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Digitalization within Logistics Management

An increased use of digital tools on the construction site

Master's thesis in Design and Construction Project Management

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Digitalisering inom logistik
En ökad användning av digitala verktyg på byggarbetsplatsen

Examensarbete inom masterprogrammet Design and Construction Project Management

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Abstract

Digitalization has been a subject in focus in the construction industry for a long time. Despite this, little focus has been placed on digitalization in the logistics management in the construction industry. This study examines partly the current picture of the digital level of logistics management today at the construction site and analyzes the opportunities and challenges to achieve increased efficiency in the future.

The study aims to map and identify the various challenges and barriers that have contributed to the current situation today. Furthermore, the study identifies potential opportunities and solutions to increase the efficiency of logistics management, but also with the aim of increasing safety at the construction site.

Comprehensive literature studies have been conducted as a basis for analysis and in order to further carry out an empirical study. The empirical study consists mainly of interviews with Skanska at both an operational and central level, but also interviews with external parties such as Autodesk and DHL have been conducted. The external parties have broadened the perspective of the study in order to see the opportunities and the possibilities available on the market today.

The study has concluded that there are great development potentials to streamline logistics management on the construction site in the future. A more digital way of working provides opportunities for simplified planning and can contribute to a reduced number of deliveries, which in turn can contribute to better process control. This gives officials on the construction site the opportunity to more efficiently plan the deliveries as well as the unloading process, which leads to a safe unloading process while reducing administrative time.

Another development potential is found in planning of Construction Logistics Plan (CLP) and the design of the construction site. There are already today, opportunities to use in order to plan the design and the layout of the construction site in 3D. Such planning enables an increased ability to predict risks at an early stage of planning, but also an improved ability to optimize the logistics flow on the construction site can be gained. The report's results also indicate that there are clear cultural and organizational challenges with the development of digitalization today.

Key words: BIM, Construction Industry, Digital tools, Digitalization, Efficient logistics flow, Logistics, Logistics Management, Safety.

Sammanfattning

Digitalisering har varit ett aktuellt ämne i byggbranschen under en lång tid. Trots detta har lite fokus lagts på digitalisering inom logistikarbetet inom byggbranschen. Denna studie undersöker dels nulägesbilden av den digitala nivån på logistikarbetet på byggarbetsplatsen idag samt vilka möjligheter och utmaningar det finns för att uppnå en ökad effektivisering i framtiden.

Syftet med studien är att kartlägga och identifiera de olika utmaningar och barriärer som bidragit till att nulägesbilden är den faktiska idag. Vidare identifierar studien potentiella möjligheter och lösningar för att öka effektiviseringen av logistikarbetet men också i syfte att öka säkerheten på byggarbetsplats.

För informationsunderlag till analys har det bedrivits omfattande litteraturstudier för att vidare kunna utföra en empirisk undersökning. Den empiriska undersökningen består främst av intervjuer med Skanska på både en operativ och central nivå men även intervjuer av externa parter så som Autodesk och DHL. De externa parterna har breddat perspektivet på undersökningen i syfte att se möjligheter och det utbud som finns på marknaden idag.

Studien har kommit fram till att det finns stora utvecklingspotentialer för att kunna effektivisera logistikarbetet på byggarbetsplatsen i framtiden. Ett mer digitalt arbetssätt ger möjligheter till en bättre planering och kan bidra till ett färre antal leveranser som i sin tur kan bidra till en bättre processkontroll. Detta ger tjänstemän möjligheten att enklare och effektivare planera sina leveranser samt lossningsarbetet vilket leder till att lossningen sker på ett säkrare sätt samtidigt som administrativa tiden minskar.

En annan utvecklingspotential finns i APD-planering och utformningen av byggarbetsplatsen. Det finns redan idag möjligheter att använda sig av verktyg som kan planera utformningen av arbetsplatsen i 3D. En sådan planering möjliggör en ökad förmåga att förutse risker och i ett tidigt skede i planeringen men även en förbättrad förmåga att optimera flödet på arbetsplatsen. Rapportens resultat antyder även på att det finns tydliga kulturella och organisatoriska utmaningar med utvecklingen av digitalisering idag.

Nyckelord: Arbetsmiljö, BIM, Byggbranschen, Digitala verktyg, Digitalisering, Logistik, Säkerhet.

Preface

The Master's thesis was written during the spring of 2020 in collaboration with Skanska and the Department of Architecture and Civil Engineering at Chalmers University of Technology.

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Olle Drugge



Reza Rezaei

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1 Introduction

1.1 Background

Digitalization has been a subject in question in the AEC industry in recent years. The construction industry is undergoing a transformation in digitalization that affects the entire chain through planning, production to the facility management. Sandblad, Gulliksen, Lantz, Walldius and Åborg (2018) believe that digitalization will continue to develop at a high rate. This means that constant skills development and improvement work will be necessary to exploit the potential that exists in the digitalization of working methods (Sandblad et al., 2018). Nevertheless, the construction industry is one of the industries that are lagging behind in the process of digitalization (Svensk Byggtjänst, 2017). The report Bygg 4.0 (Vinnova, 2016), which is based on interviews with experts in the construction industry, finds that there are great opportunities to raise the quality and lower the costs for the final product by help of digital solutions. One area where digitalization has a major impact is precisely digital tools at the construction site (Vinnova, 2016).

The construction process requires a well-planned logistics and logistics management to function optimally (Dubois, Hulthén and Sundquist, 2019). Logistics is a major part of the construction process that, with the management of it, can reduce time and cost. Successful construction logistics management (CLM) practices are according to a high number of literatures interpreted as having the right material, in the right quantity, in the right place, at the right time (Whitlock, Abanda, Manjia, Pettang and Nkeng, 2018). Logistics management is one of the key factors affecting the performance of construction projects. CLM disciplines focus on timely delivery of resources (whether it is information resources or building materials). Construction logistics involves the coordination of on-site delivery, the layout of the site itself and the allocation of material resources from the point of delivery to the work surface which have to be actively managed in order to have a positive outcome (Whitlock et al., 2018).

A recurring problem in the construction industry and for Skanska has been difficulties with logistics management on site. The major accidents with fatal outcome in Skanska in the recent years have been associated with heavy machines, trucks and unloading of materials on the construction site. These have been caused by various deficiencies in logistics management. As mentioned earlier the construction process requires a well-planned logistics and logistics management to function optimally (Dubois et al., 2019). Digital solutions, work-sets, tools and methods can help Skanska to increase safety on the construction site, and also increase the productivity and profitability in their projects (Skanska, 2019).

1.2 Purpose

The purpose of this study is to identify which digital tools are being used in the case company Skanska's work within logistics management on the construction site, as well investigate possibilities and opportunities for improvement and further digitalization within the logistics management. The study should also enlighten the obstacles and barriers that may prevent further digitalization in Skanska's logistics management on the construction site and come up

with possible solution to overcome these obstacles and barriers. The study also aims to investigate the impact that digital tools can have on the safety on the construction site.

1.3 Delimitations

The study was conducted on behalf of Skanska's business unit House Gothenburg. Therefore, the study has been limited to investigate this specific business unit.

What is defined as digital tools are software and applications suitable for the construction industry. Skanska uses both internal applications that the company itself has developed and external applications which have been developed by companies other than Skanska, or they have been developed in consultation with other companies. Both internal and external digital tools are included in the study. Windows Office packages that include Excel, Word and PowerPoint are not included in the study since these are not developed specifically for the construction industry.

Construction logistic management is normally defined as the process of planning, implementing and controlling supply chain resources (Whitlock et al., 2018). This study will delimitate logistics management into the planning and monitoring of transport flows of the vehicles into and on the construction site. The study will not include the logistics processes of the materials after their unloading from the transport vehicles, such as logistics planning and monitoring of storage areas and material movement flow on the construction site. Therefore, the definition of logistics management in this study will be the following; planning and monitoring transport flows of the vehicles into and on the construction site.

1.4 Research Questions

- How can an increased use of digital tools on the construction site affect construction logistics management (CLM)?
 - What is the current status of using digital tools in CLM?
 - What are the obstacles of implementing digital tools in CLM and what barriers must be overcome to enable this implementation?
 - How can the safety on the construction site increase by using digital tools in CLM?

2 Method

The following chapter presents the report's method and work process. The choices made during the process and the reasons for the choices in each step to achieve a good research quality is presented here. The report is based on an inductive approach and a qualitative research strategy. The data collection method consists of a total of ten interviews with selected interviewees from Skanska, Autodesk and DHL. A pre-study was conducted in the beginning of the study. The pre-study consisted of an observation study from one of Skanska's project, Citygate together with four unstructured interviews. The aim with the pre-study was to identify a problem, to define the delimitations of the study and to determine the research questions.

2.1 Design of the Study

Since the study did not have a formulated hypothesis, an inductive approach was chosen. To be able to collect data for the basis of an analysis, three choices were made step by step. The first step was choice of research strategy, the second step was the choice of research design and the third step was the choice of data collection method.

2.1.1 Approach

The work is based on an inductive approach, which means that the study is based on several identified problems and then a greater and deeper understanding of these problems is made. According to Blomkvist and Hallin (2015), the inductive approach is best applied when the problem formulation is identified, and no in-depth hypotheses is needed to be developed. The alternatives to an inductive approach are deductive and abductive approaches. A deductive approach means formulating a hypothesis based on literature and then a study is done to verify the hypothesis, or to come up with another answer than the hypothesis (Blomkvist and Hallin, 2015). Abductive approach is a combination of both inductive and deductive approaches. Hence the problem for this study already was identified and no hypothesis was formulated, the choice fell naturally on an inductive approach.

2.1.2 Research Strategy

According to Björkqvist (2012), the research questions must be chosen before the choice of method. Then the choice of method is adapted based on the research questions, since all questions require different methods. Björkqvist (2012) also considers that qualitative studies are usually best suited to studies with inductive approaches. Since this study is based on an inductive approach and the questions of this study require descriptive answers, a qualitative study is best suited. According to Wallén (1996), there are varying views and opinions regarding qualitative studies. Everything from that it is highly unscientific to that qualitative studies are the only meaningful studies. But Björkqvist (2012) is considering that one method would be better than the others as completely wrong. An example Wallén (1996) uses is that one cannot measure how good one computer is by only measuring its speed and memory. The aspect of how the individual who will use the computer is able to manage and utilize the computer's full capacity needs to be considered. This is an example that shows that qualitative studies are not limited to certain areas but rather can be applied to all research areas which holds some form of practical activity. However, qualitative studies need to be motivated in a study since they do not contain value by themselves (Wallén, 1996).

In the beginning of the study a pre-study was conducted. The pre-study consisted of an observation study from one of Skanska's project, Citygate together with four unstructured interviews of central officials at Skanska. The observation study consisted of participation of several meetings and workshops as well as dialogs about the subject with officials at the project office of the Citygate project. The interviewees of the unstructured interviews had positions such as, Regional Health and Safety Manager, Design Manager and Digital Leader. The aim with the pre-study was to identify a problem identification, to define the delimitations of the study and to determine the research questions for the study.

When the authors of the study had formed a good picture of the subject through an extensive literature study and a pre-study, a problem identification was designed for the study. Thereafter, the delimitations of the study were set and finally the research questions were determined. Then, the data collection and interview process began.

2.1.3 Research Design

Research design is a model for how the problematization can be investigated. The research design should be chosen after the research strategy is chosen (Blomkvist and Hallin, 2015). The authors of this study did choose case study as research design because it was best applied and suitable considering the purpose of the study. Case study involves an empirical investigation of a certain contemporary phenomena in its real context with multiple sources of evidence (Robson and McCartan, 2016). This study concerns the digitalization, which is one contemporary phenomena, the choice of case study as a research design to investigate Skanska's work with logistics management on the construction site became a matter of course.

2.2 Literature Review

In order to be able to understand and analyze the situation at the construction sites today regarding digitalization in logistics management, theory and knowledge about the various underlying topics and factors that created these conditions are required. Theories are also needed to understand what affects the evolution of digitalization in the future. Knowledge of this is important in order to be able to analyze the data collection later.

In the literature study, previous studies in the subject, books and scientific publications were studied. The reason was to create a broader picture of the subject and how the development has taken place in recent years. The search of literature was mainly done with the help of Google Scholar, Chalmers Library and websites from authorities, but also other relevant books were used during the study. Keywords such as BIM, digital tools, construction site, construction logistics management, supply chain, Construction Consolidation Center, logistics, logistics in construction, lean supply system, user-friendliness and change management were used in the search.

2.3 Data Collection

The data collection for this study was done through qualitative and semi-structured interviews with selected interviewees with different experience and titles from Skanska. Semi-structured interviews were also conducted with selected interviewees from the software company Autodesk as well as one unstructured interview with one of Skanska's contract persons at the

logistic company DHL. The interviewees are presented in more detail in subsection 2.3.2. The interviewees were selected by recommendations from the supervisor of the study at Skanska together with recommendations from the pre-study.

2.3.1 Interview Methodology

According to Bell (2016), interviews are an important research tool in a qualitative research. The reason behind choosing interview methodology as data collection method is based on the qualitative strategy chosen but also because interviews are one of the most common data collection methods regarding the collection of empirical data (Blomkvist and Hallin, 2015).

In the beginning of the interview process a selection of the interviewees was made. The selection was conducted in a collaboration with the authors' supervisor of the study at Skanska together with the result from the pre-study. The supervisor at Skanska has the following title, Digital Development Manager in Skanska's department for Operational Support in Gothenburg. The selected interviewees from Skanska for the empirical data collection had the following positions; Logistics Coordinator, Logistics Manager, Production Manager, Construction Supervisor, Digital Block Manager and Logistics Engineer. The interviewees from the software company Autodesk had the following titles, Senior Manager and Technical Solutions Executive. These interviews were semi-structured, and an interview template was formed before the interview took place. An unstructured interview with one of Skanska's contacts persons at DHL also took place during the empirical data collection process of interviews. The interviewees are presented further in this section.

The interviews with the interviewees from Skanska took place before the interviews with the interviewees from the external companies, Autodesk and DHL. The reasons behind this was to first analyze Skanska's work with digital tools within the logistics management and discover their challenges within the subject, but also analyze the causes behind them. To later get an external point of view of the subject and the research questions from other dependent parties in the area.

2.3.2 Interviewees

Below, the interviewees from the empirical data collection interviews are presented.

2.3.2.1 Logistics Coordinator

The Logistics Coordinator was responsible for all the planning and execution of the logistics at a construction site. He/she had worked with logistics in the construction industry for eight years and been located on various hospital projects during that time. Today he/she was located at a hospital project outside of the city core of Gothenburg.

2.3.2.2 Logistics Manager

The Logistics Manager is a tailor-made role for the project, Citygate. This role was needed due to the complicity of the logistics challenges in this project. The Logistics Manager had over ten years of experience of logistics management at construction sites. The Citygate project will be further described in section 3.1 about Skanska.

2.3.2.3 Production Manager

The Production Manager role means directing and managing everything that has to do with production, his/her main responsibility is for the schedule and distribution of work among all officials. The Production Manager had over 12 years of experience of this role and were located at the Citygate project that will be further described in section 3.1 about Skanska.

2.3.2.4 Construction Supervisor 1 and 2

The Construction Supervisors had three and two years of experience respectively. They both were Digital Leaders, a formal role within Skanska that will be presented further in subsection 3.1.1 about Skanska. They were in a larger residential project in the outskirts of Gothenburg. The project had a lot of space on the construction site during the first part of the project, but later into the project it would change into a smaller surrounding area on the construction site. The change in space would cause more challenges regarding logistics management at the construction site ahead.

2.3.2.5 Digital Block Manager

The Digital Block Manager had a similar role as the Construction Supervisors but in a different project with more responsibility. She/he was also a digital leader whereas he/she had more responsible for pushing the digitalization forwards in the project. The Digital Block Manager was located at the Citygate project that will be further described in section 3.1 about Skanska.

2.3.2.6 Logistics Engineer

The Logistics Engineer works with logistics at a central level at Skanska. He/she is an in-house consultant and supports projects in all southern Sweden with logistics challenges daily.

2.3.2.7 DHL

The logistics company DHL has a collaboration with Skanska regarding logistics solutions. This means that DHL has a special department that only works towards Skanska and their business. The contact person interviewed at DHL was working in this department on an operative level.

2.3.2.8 Autodesk

The interviewees at Autodesk had the following titles; Senior Manager and Technical Solutions Executive. They were both located in the United States of America. They both had many years of experience from working with digital solutions within both the AEC industry as well as the manufacturing industry. Skanska and Autodesk are currently investigating the possibility of entering a close collaboration with each other. The goal of this is to gain a higher understanding of each other's organizations and challenges. This is in order to be able to use each other's competences more effectively in the development of digital tools in the future.

2.4 Processing of Data

In order to perform a good and credible analysis, the data collected must be processed efficiently. In this way, maximum benefit is obtained of the empirical study for the analysis. The empirical data from the interviews became extensive as the interviews were semi-structured and that different follow-up questions with new angles emerged. The data from the

interviews were processed and compiled by going through both audio files and notes from the interviews. Then the data was categorized into short points. In this way, clear comparisons between the data from different interviews could be made to see similarities and differences. Furthermore, the problems that existed were identified. The compiled data is then used to further analyze the problems.

2.5 Validity

During the process, a critical source view was used during the literature study in order to have a high validity on the study. This was achieved by searching for multiple sources that reinforce the same assertion as well as being critical of sources that may be biased or misleading. An awareness that the different interviewees may have had different attitudes towards the topic has also been taken into account, therefore a critical review of the data from the interviews has been conducted.

Furthermore, the interviews were conducted with officials with different experiences and perspectives on the subject to strengthen the validity of the data from the officials at Skanska. There has also been a variation on different types of construction projects that the various officials had experience from, which gives the results and data from the interviews a higher validity.

During the study, it has been discussed whether experts and interviewees with whom the study has been in contact with may have affected and influenced the analysis of the study. The fact that the study is impartial is important in order to maintain the validity of the study.

The fact that the report is anchored and supported by the empirical data with theory increases the validity of the study and at the same time provides a stable basis for a future analysis.

In order to increase the validity of the study, certain elements could have been made better. The interview process could have been more extensive, for example, an increase in the number of interviewees, the variety of their backgrounds and position, and a greater geographical spread in construction project investigated could have contributed to an increased validity in the study.

3 Case Company

In this chapter the case company Skanska is presented. This chapter begins with a brief of Skanska and one of their biggest projects in Gothenburg. Furthermore, their work with digitalization and their journey is presented. At the end of this chapter, Skanska's efforts and outlook on safety and work environment safety is presented.

3.1 Skanska

One of Sweden's largest construction company, Skanska, has been chosen as the case of this study mostly due to that the study was conducted on behalf of Skanska's department House Gothenburg. Skanska is one of the leading construction company regarding digitalization in Sweden which make Skanska a suitable case for this study (Digital Development Manager, personal communication, December 12, 2019). The observation study was conducted on one of Skanska's project Citygate. Citygate was chosen because of the circumstances regarding the project, the project is both a pilot project regarding digitalization and a project facing many difficulties regarding logistics. Citygate will be the highest commercial building in the Nordic countries when it is completed with its height of 144 meters. The building will be developed on a small piece of land, almost as the size of the actual building in the city of Gothenburg. The construction site will be surrounded with emergency routes for a fire station. Therefore, no transportation will have the possibility to whether stop or wait outside of the project area. The small area of the construction site also unable the possibility for vehicles to stop inside the construction site for a longer of time as no vehicles can pass each other on the construction site due to lack of space. This creates a great demand on the planning and monitoring of the logistics. This in combination of the pilot project of digitalization makes Citygate to a great project to conduct an observational study on.

3.1.1 Digitalization

About five years ago, Skanska set a goal to become the leading construction company within digitalization (Digital Development Manager, personal communication, December 18, 2019). In order to achieve this goal, Skanska started a time limited development program called GoMobile. The idea of GoMobile was to produce simple technical applications and support the employees' daily work. The objective was that all the employees in the projects and in the support functions, should easily take use and be able to share relevant information at the construction site and the office. GoMobile aims to improve the efficiency and the quality of sharing information with the stakeholders through an increased possibility of sharing data, documents and drawings on mobile devices. During the GoMobile program a digital project platform was developed, the platform was first developed by Microsoft and then further developed by Skanska's project group GoMobile. The platform provided every project with a cloud-based service where every stakeholder of the project could share information for the project. The digital project platform was intended to be used via computers and via applications on tablets and phones outside on the construction site.

Two years ago, Skanska's investment in digitalization increased further (Digital Development Manager, personal communication, December 18, 2019). When the digitalization program GoMobile came till an end, a new division on Skanska was created, the DigiHub. The DigiHub is today consisting of 12 individuals who actively works with digitalization, development and

3.1.2 Safety

Skanska constantly works with occupational safety issues and has high ambitions when it comes to this issue (Health and Safety Manager, personal communication, December 4, 2019). Skanska has a saying in their organization “*work safely or not at all*” that mirrors their ambition. They also have a pronounced vision to zero occupational accident in the future. According to the Health and Safety Manager (personal communication, December 4, 2019), loading and unloading is mentioned as one of the riskiest operations on a construction site in Sweden.

During the last three years, three tragic accidents have occurred with connection to unloading of material on the construction site (Health and Safety Manager, personal communication, December 4, 2019). These three accidents led into the death of three human beings. Important to mention is that those are the only accidents with fatal outcome in Skanska which stress the importance of looking more into the subject of improving the logistics management on the construction site.

All accidents and incidents at Skanska’s construction sites are registered in a system called BIA (Bygg- och anläggnings-branschens Informationssystem och Arbetsmiljö; English: Construction industry’s Information system and Working environment) (Health and Safety Manager, personal communication, December 4, 2019). IA is a system used in different industries and BIA originate from IA but is used in the construction industry whereas the B in BIA stands for construction. It is a system developed by an insurance company named AFA Försäkringar. The IA system is primarily designed to deal with deviations within the working environment but can also be used in the areas of quality, environment, property, security and to capture improvement proposals. By doing this, Skanska get to know why unwanted events happen in their construction sites. Skanska’s aim is to use this knowledge to prevent new accidents from happening in the future.

4 Background Study; Literature Review and Initial Interviews

This chapter covers all the secondary data needed to create a deeper understanding of logistics management and its digitalization in the construction industry and lay the foundation for the report's upcoming analysis. This chapter begins with a general description of logistics and logistics management and further describes the factors, tools and theories needed for later analysis.

4.1 Logistics

There are many different definitions of logistics in different industries and context but according to Jonsson & Mattson (2011) logistics can be described as the knowledge of efficient material flows. Logistics is aimed at all the businesses that ensure that materials and goods are in the right place at the right time. But also, to ensure that all stakeholders receive increased financial gain. Logistics is not just a number of techniques, methods and tools, it can be seen more as an approach and is one of the most important elements of a construction project. Transport and distribution or logistics in general have a critical impact on the site performance factors such as time, cost and plan reliability, and on industry performance indicators such as accident statistics (Sullivan, Barthorpe and Robbins, 2010). Transport and distribution can therefore be mentioned as the cornerstones of logistics and are the main tasks that can be demonstrated visually in logistics (Agapiou, 1998). According to Storhagen (2011), the logistics concept includes seven Rs which are presented below:

1. Obtain the **right** product or service
2. In the **right** quality
3. In the **right** condition
4. In the **right** place
5. At the **right** time
6. With the **right** customer
7. At the **right** cost

These R represent the objectives of logistics and shows that the customer focus in the logistics work is governed by the customer's wishes and needs. This is where competitive advantages can be achieved in a competitive industry by offering high customer service and offering something special (Storhagen, 2011). The goal of logistics lies in combining high customer service with low costs and little tied up capital (Jonsson, 2008). This can advantageously be applied in the construction industry and if it is planned from a logistical perspective from the beginning, productivity can be significantly improved (Agapiou, 1998)

4.1.1 Logistics in Construction

Logistics in construction involves several different activities such as goods and material storage, transportation and distribution and also planning of the site's layout which requires an active management of site evolution as the construction processes move further (Sullivan,

Barthorpe and Robbins, 2011). The dynamic of building processes and the site conditions together with time and space are the conflicts that are to be handled in order to have a safe and even flow of materials and movements on the construction site (Whitlock et al., 2018). According to Whitlock et al. (2018) a best logistics strategy evolves typically from a Construction Logistics Plan (CLP). CLP is a drawing of the construction site that among other things, visualizes the locations of materials, location for cranes, roads for transport and signboards on the construction site. CLP is developed by the main contractor and is critical for the logistics efficiency and transport flows and is progressively developed as the project moves forward.

4.1.2 Traditional Construction Logistics

Sullivan et al. (2010) describe the traditional construction logistics as uncontrolled, inconsiderate, disruptive and wasteful. Traditionally, logistics in construction has not been a subject in focus, the focus has only been on the final material delivery which has been recognized as an important activity in the traditional way of thinking. The nature of construction industry and forms of contract has enabled to outsource the work and risk which in turn has fragmented the site's supply-chain practices which are still unsophisticated (McKinsey, 2015). This had led to a situation where no one had overall control of a project logistics and resulted in unsatisfactory.

4.1.3 Delivery Management System

Every construction project is unique with its own conditions and limitation. The special characteristic conditions of a construction site make having a delivery management system very important (Whitlock et al., 2018). The variation of project's size and site's condition makes logistical complexity and the delivery management system by high importance to enable managing the logistic to and at the site. A delivery management system can be explained as a system based on detailed methods, procedures and routines to facilitate and carry out a specific task, delivery or activity on the project site (Whitlock et al., 2018). A well-detailed and defined delivery management system can provide a clear view for planning and executing the deliveries and the logistic at the site (Ballard and Hoare, 2015).

Lack of a delivery management system or an unclear delivery management system can create difficulties which may cause different problems (Whitlock et al., 2018). An early delivery of materials on the site will occupy space unnecessarily beside the fact that the materials can be damaged and get loss during the time it is stored at the site. A late delivery, on the other hand can stop the production and put the work flow on hold.

4.1.4 Just-In-Time Delivery

Just-in-time delivery method is one of the most common and well-known delivery methods in construction logistic management (Lundesjö, 2015). In a Just-in-time delivery, the materials or equipment are delivered to the site as close as possible to the time for their usage. This method gives the opportunity to execute the task on time without any need of using storage area at the site. The decreased risk of damage and loss by storing the goods on site can also be mentioned as another benefit with this delivery method. However, since the deliveries and logistics in construction are affected by external influences such as weather conditions and site topography,

some inefficiencies and uncertainties may appear in just-in-time delivery method compared to its level of certainty within manufacturing industry (Sullivan et al., 2011).

4.1.5 Push and Pull System

There are mainly two general systems for material flow, the push system and the pull system. The push system is based on a fixed production plan and schedule, where the material is constantly pushed further into the production chain. This means that interruptions that occur in production are taken up by intermediate storage and production buffers (Storhagen, 2011). This system can provide in longer lead times, as a result of queuing and waiting times, and greater tied-up capital (Lumsden, 2006).

In a pull system, it is the further instance in the production chain that calls on the previous instance's attention for its need of material. In this way, overproduction and tied-up capital in intermediate stocks are avoided since each instance in the production chain only produces the amount needed by the further instance (Storhagen, 2011). The disadvantage of pull systems is vice versa of push systems, where some instances sometimes have no operations due to need of the further operation but instead the tied-up capital can be reduced in this system (Lumsden, 2006).

4.1.6 Construction Consolidation Centre

Construction Consolidation Center (CCC) also known as logistic center or logistics hub is an appropriately located storage facility where the materials are stored for a limited time before distribution to the construction site (Sullivan et al., 2011). A Construction Consolidation Center has normally a strategic location, normally close to motorways to provide more facilitated deliveries to the site (Allen, Browne, Woodburn and Leonardi, 2014). The first Consolidation Centers used in construction projects were established in London and Stockholm in 2001 (Sullivan et al., 2011). Although the projects were totally different, both projects used the same concept and had the same purpose with Consolidation Center, to maximize the logistical efficiency. Having a Consolidation Center will provide an opportunity to more efficient and sequenced deliveries to the construction site. Another advantage gained by having a Consolidation Center is the ability to control the goods and detect errors and damages in advance.

4.1.7 On-Site Storage

On-site storage technique is a logistics technique where the goods and materials are temporary stored at the site (Lundesjö, 2011). Harker, Allcorn and Taylor (2007) describe the on-site storage technique as a temporary storage area for materials and tools that are widely used on the site. The risk of damage and loss by storing the goods on site are high in this technique.

4.1.8 Challenges within Logistics Management

Mobasheri and Mohamed (2019) have done a bachelor's thesis at Royal Institute of Technology about improved logistics by using BIM. In the thesis, a survey was conducted which shows inefficiencies within the construction logistics management. Parts of the result is presented in this subsection and pie-charts of the result is shown down below.

The survey enlightens that the material flow on the construction site is not free of issues. Diagram 3 shows that the workers are not completely satisfied with the delivery and material placement on site. A solution may be to use Just-in-time as a logistical strategy, it avoids storing goods on site and reduces deficiencies in material flow.

Diagram 1 clearly shows that the communication and information flow between the management and the skilled workers is not quite perfect which can lead to misunderstandings on the construction site. Use of delivery labels on goods can help skilled workers avoid such misunderstandings. By sharing the incoming information with all the parties working on the construction site, a holistic view of the project can be gained. According to Granroth (2011), it helps the parties to visualize a project and communicate it better when everyone has a common idea and understanding of tasks that needs to be done.

The fact that 89 % answered yes to the question of if the production has been stopped due to lack of logistics management in Diagram 4, is interesting according to Mobasheri and Mohamed (2019). It shows that logistics management plan has failed in one way or another since the production could not avoid a stop. Mobasheri and Mohamed (2019) mention the importance to plan the logistics at an early stage as detailed as possible and anticipate the problems that may arise as production starts. Already in the design phase is it possible to calculate approximately 4D BIM time frames for scheduled activities and to prepare the ordering of materials to the extent that fits the schedule. Therefore, it is also interesting to see how Diagram 2 has been answered for the use of BIM at the construction site.

Diagram 2 shows that the use of a BIM model as a starting point for logistics rarely occurs. The fact that the BIM model is not used on the construction sites clearly shows that the view of BIM as a joint work tool is very limited. It can be interpreted as logistics not being digitized to a greater extent. Often, traditional work is usually done on paper, i.e. 2D drawings and with this, the risk of carelessness is increased due to the human factor.

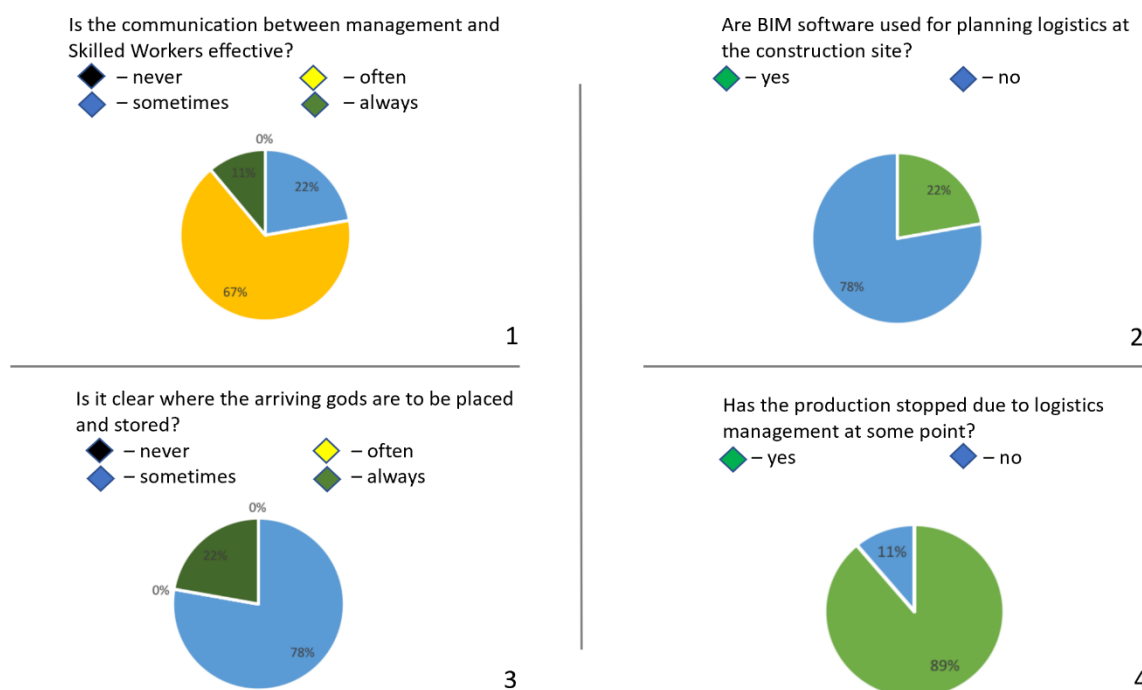


Figure 2: Result from survey conducted during a bachelor's thesis by Mobasheri and Mohamed (2019)

4.2 Lean

Lean is an ideology that aims to maximize customer benefit while minimizing waste of resources through various types of streamlining and rationalization (Lean Enterprise Institute, no year). The term “lean” has only existed since 1990. Previously it was called TPS (Toyota Production Systems) and then aimed at the origin of the concept in the Japanese company Toyota but has later been spun off by several other organizations. TPS was based on two concepts; "*Jidoka*" which can be translated into automation with a human touch and "*Just-in-Time*" which means that each process produces just what is needed for the next process, creating a flow. Toyota's production system TPS aims to obtain the highest quality, shortest lead time and lowest cost (Bicheno, Holweg, Anhede and Hillberg, 2011).

Just-in-time is about the flows of production, information and material handling in a company and means that they should run smoothly and predictably at the rate the customer demands for the product or service (Bicheno et al., 2011). This fits repetitive tasks especially well, for example, planning is facilitated. Jidoka means that quality is built into a product or service from the start in order to avoid late costly errors e.g. warranty.

4.2.1 The Theory of Swift Even Flow

Schmenner and Swink (1998) describe the theory of Swift Even Flow as a theory based on several concepts in order to increase a process's productivity. The theory describes that the more even a flow of material are through a process, the higher will the productivity of that process be. This means that productivity in a process increases through a faster even flow, i.e. lead time. On the other hand, the productivity decreases as variation increases in the flow. The variation refers to both variation in demand and variation in the number of steps in the process itself. This theory provides an underlying starting point that should be explained in order to understand how the process is affected (Schmenner and Swink, 1998).

The following reasoning is based entirely on Schmenner and Swink (1998). The first concept is about value creation and non-value creation activities. According to the theory, all activities in a process can be divided into either value creating or non-value creating activities. All activities in a process that transforms materials to increase the quality of the product can be interpreted as value creating activities. Activities aimed at moving, categorizing or inspect is considered non-value-creating as they do not add increased customer value. These activities can be categorized as "waste" or abundance. By reducing or eliminating the parts of a process that do not add value, productivity can be increased as the flow of material will move faster.

The second concept presents bottlenecks that are linked to the process lead time and is a comparing of how fast a flow is in terms of how long it takes from start to finish (Schmenner and Swink, 1998). Bottlenecks are parts of a process where production slows down or stops. By reducing the bottlenecks, lower lead times can be achieved, also a faster and more even flow of material throughout the process. Another concept that is introduced in the theory is variation that should be reduced to obtain an even flow (Schmenner and Swink, 1998). The variation relates to the demand in the process or how different activities in the process are performed as well as how many steps are included in the process. The variation in a process is reduced as the demand for the process is uniform and continuous. A more equalized demand and minimized irregularity reduces the variation and increases the productivity and provides a more even flow. The theory of Swift Even Flow also includes an aspect of quality that should

be considered in a process (Devaraj, Ow and Kohli, 2013). High quality in a process is of great relevance as it helps to reduce variation and to avoid bottlenecks. As the concepts in this theory aim to increase the quality of the outcome by supplying products or services that are of high quality and produced quickly, quality is a central role in designing productive processes (Schmenner and Swink, 1998).

4.2.2 Lean Supply Systems in Construction

Arbulu and Ballard (2004) describe a strategy to develop a more efficient supply system at the construction site by implementing principles and techniques of Lean. The objective by this implementation is to ensure on-time delivery of materials to the construction site while minimizing the cost and the waste of resources to maximize the final value of the customers. The purpose for achieving this objective is to develop a supply management system with minimal waste; e.g., low supply and demand reliability, large inventories not needed to absorb variability, and physical waste.

The strategy is proposing the implementation of the following 8 parts (Arbulu and Ballard, 2004):

1. The first part is to use a digital tool based on the Last Planner System to control the production on site to increase the workflow reliability. This digital tool is meant to work in conjunction with the already existing processes and tools. Last Planner System is a method of co-design where the project's key players work together.
2. Create a link between the digital tool and the material management process.
3. Apply the Construction Consolidation Center concept as a part of supply system.
4. Prepare assembly packages at the CCC a day before their usage on site. The digital tool can be used to save and send the information between the CCC and the site in order to have the right packages at the right time on the site.
5. Use the pull method to deliver the assembly packages. The existence of the digital tool is by high importance in this part to avoid pushing the materials to the site. This will reduce the waste and will provide in a better control over the spaces at the site.
6. Define and design a supply system based on the production demand and Kanban techniques.
7. Define a standardized supply system and design pre-assembly strategies, e.g. pre-assembly can take place at the CCC or at suppliers' facility.
8. Minimized material lead times in the supply-chain in order to achieve a faster delivery, a reduced disruption risk due to changes and a great window of reliability.

4.3 Digitalization

Digitalization has been an up-to-date and an in-question subject in the past years in a wide range of industries. This era of digitalization has resulted in an enormous increase in productivity, product quality and product variety (Koch, 2019). The construction industry is one of the industries that is furthest back in the digitalization journey, this is shown in the figure below (McKinsey, 2015). This depends partly on the low degree of R&D investments and lack of understanding of long-term benefits but also the technical challenges within the industry is one of the reasons behind this slow pace of digitalization. According to McKinsey (2015), less than one percent of revenues in the construction industry is spent on R&D while 3.5 percent is the respective investment in the auto industry. Therefore, there is still a lot of possibilities and opportunities in the construction industry's digitalization. Today, there is a lot of focus on BIM in the industry.

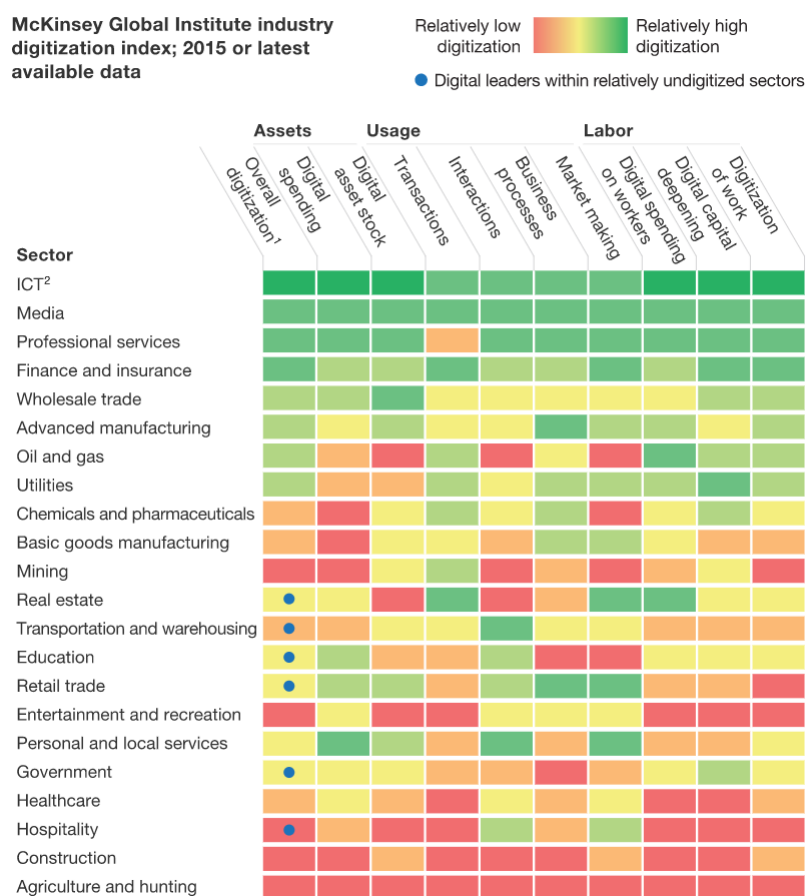


Figure 3: A visualization that shows the construction industry is among the least digitized industries (McKinsey, 2015)

4.3.1 BIM

Building Information Modeling (BIM) is an information management method for construction that usually consist of a digital model that is created in a building process for design and visualization with the aim of gathering information about the building and the processes and decisions surrounding the building (Borrmann, König, Koch and Beetz, 2015)). A BIM model can be seen as a virtual model of the reality. The model collects and organizes all information from a building's life cycle. The BIM model can contain semantic information, including

function, materials and relationships between the objects and the building itself. The real content of a BIM model can vary a lot depending on the usage of the model. The most common cases of BIM models include visualization, design coordination, drawing generation, quantity take-off, progress monitoring and facility management.

4.3.1.1 Definitions of BIM

BIM, Building Information Modeling or also recently mentioned as Building Information Management is defined differently by different institutions and organizations. In other words, there is a lack of universal definition of the concept of BIM and what a BIM-model should actually provide. The variety depends heavily on the purpose of the model and thereby can its definition vary as well (Migilinskas, Popov, Juocevicius and Ustinovichius, 2013). Below are three different definitions by three different organizations:

1. American Committee of the National Information Model Standard Project Committee defines BIM as a shared knowledge resource of physical and functional information of a facility and a basis for decision-making during the facility's lifetime (Building SMART, 2010). In this definition the model exists from the earliest conception to demolition.
2. U.S. Government General Services Administration (2007) defines BIM as the development and use of a various computer software data model to simulate the construction and operation and to document a building design.
3. British Standard Institution Specification for information (PAS 1192-2:2013), on the other hand, defines BIM more as a process of the design, construction and facility management using information about virtual objects.

4.3.1.2 BIM in 4D

4D BIM is a 3D model with a 4th dimension of time schedule where the model includes tools that link the model's objects to scheduled activities or other types of time-based simulations Eastman, Teicholz, Sacks and Liston (2011). The 4D BIM model promotes the user with a detailed simulation of the construction site over time. Whitlock et al. (2018) believe that the traditional use of real-time and high-quality walkthrough technology is adapted for individual activities, while 4D tools in BIM make it easier to predict the project's boundaries and uncertainties and are more useful from an economic perspective. This function can be applied to logistics management as well, the 4D BIM model is able to provide the logistic management team with a simulation of the construction site over time by visualizing the changes of the environment on the site in real time.

4.3.1.3 BIM in Logistics

As mentioned above BIM can be used for logistics management. Four of the benefits of using BIM in logistics management is stated below (Whitlock et al., 2018):

1. BIM can provide an improved understanding of logistics information due to its visualization-ability in 3D platforms. Complex logistics processes can easily be interpreted which can reduce the effort of identifying the logistics issues and opportunities.
2. An improvement of work environment safety can also be achieved since BIM provides a better understanding of risks associated with the logistics on the site. Unlike 2D, BIM

reduces the risks for misinterpretation and facilitate the communication due to its visualization-ability

3. A more efficient layout planning can also be mentioned as one of the benefits gained by BIM in logistics partly due to the opportunity to quickly detect potential problems associated with the logistics that may clashes with a scheduled order of work. 4D BIM enhances the progressively ongoing logistics planning with the construction operations by giving the opportunity to a facilitated coordination and control over this interplay.
4. The information of the 3D model will improve the efficiency in logistic planning. The 3D model enhances the understanding of the expected site environment which facilitate that inconsistencies are easier to detect. Furthermore, BIM software can also detect clashes and identify conflicts in the model which will reduce the time spent on reviewing and revising logistics proposals on site.

4.3.2 Artificial Intelligence

Artificial Intelligence (AI) can be described as the simulation of human intelligence processes by computer systems and machines (Poole, Mackworth and Goebel, 1998). AI collects available collective data and try to decode any available pattern or model and tries to implement machine functions to simulate basic human understanding (Vickranth, Bommareddy and Premalatha, 2019). AI uses machine learning for processes like reasoning, learning and self-correction and has the ability to execute tasks with faster speed and accuracy than a human being.

Artificial Intelligence is not widely implemented in the AEC industry today but according to Miao, Yin and Takefuji (2019), China construction industry has launched Artificial Intelligence R&D planning in 2019 and the development is expected to occur in the near future. The logistics industry, on the other hand, has come further in AI development (Robinson, 2019). In the logistics world, AI and robots are already used in the operation and embedded in the supply chain in order to optimize the operation processes.

Using Artificial Intelligence instead of traditional systems in construction will help reduce the errors and provide in an improved production system management (Vickranth et al., 2019). AI implementation in the AEC industry can result in better communication, improved relationships and reduced waste of resources in order to increase productivity and quality. Oprach, Bolduan, Steuer, Vössing and Haghsheno (2019) describe an overall objective for using AI in the AEC industry. The objective is to develop a digital platform which enables all parties to process data and make it usable regardless of the data quality or format in order to enhance the decision-making processes through collaboration between man and machine.

4.3.3 Virtual Collaborative Design Environment

Virtual Collaborative Design Environment is a collaborative design system presented by Roupé, Johansson, Maftai, Lundstedt and Viklund-Tallgren (2018). This system is an integration of a multi-touch table and VR-systems that supports interactive and collaborative design work. The multi-touch table is intended for active collaborative design where different stakeholders can work together. The Head-Mounted Display (HMD), on the other hand, is a

tool for the individual where different stakeholders can move around in the planned environment in scale 1:1.

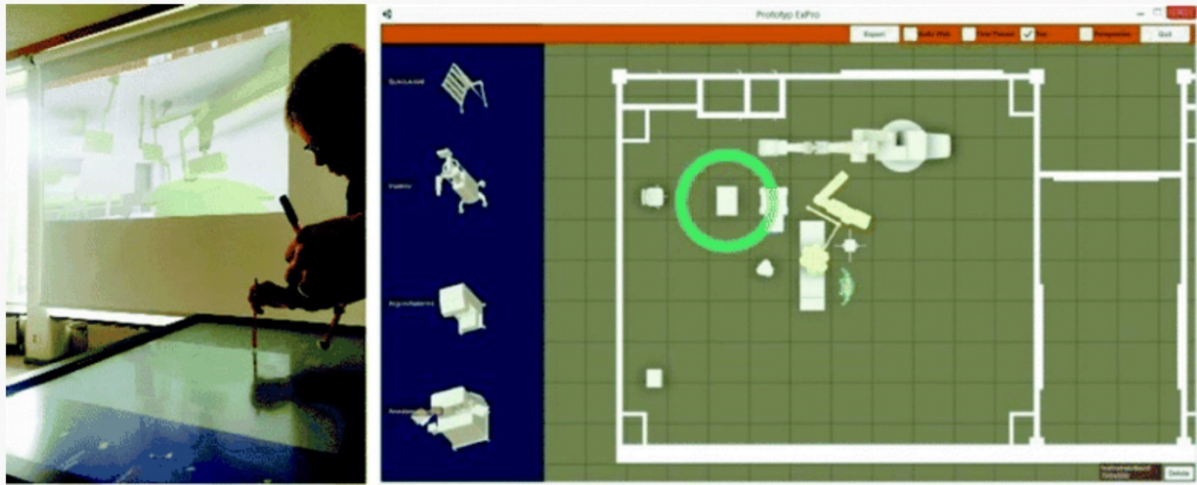


Figure 4: The picture on left side shows the multi-touch table which is used together with a non-immersive VR monitor and picture on the right side shows the layout of the multi-touch table screen (Roupé et al., 2018).

The objective of this system is to involve the stakeholders with different experiences and knowledge to understand, participate, communicate and collaborate with each other in the same room (Roupé et al., 2018). The intention of this collaborative design system is to create a system that supports a better shared design process in order to obtain a high-quality outcome. This system has been evaluated during design of two new healthcare environments with very positive outcome. The system helps the construction design team to avoid the self-made mental image based on the documents, descriptions, 2D-drawings and pictures and avoid misinterpretation of the healthcare specialists' feedback. Instead, they will communicate and collaborate with each other and use this system which help them to utilize more knowledge and ensure a high-quality outcome.

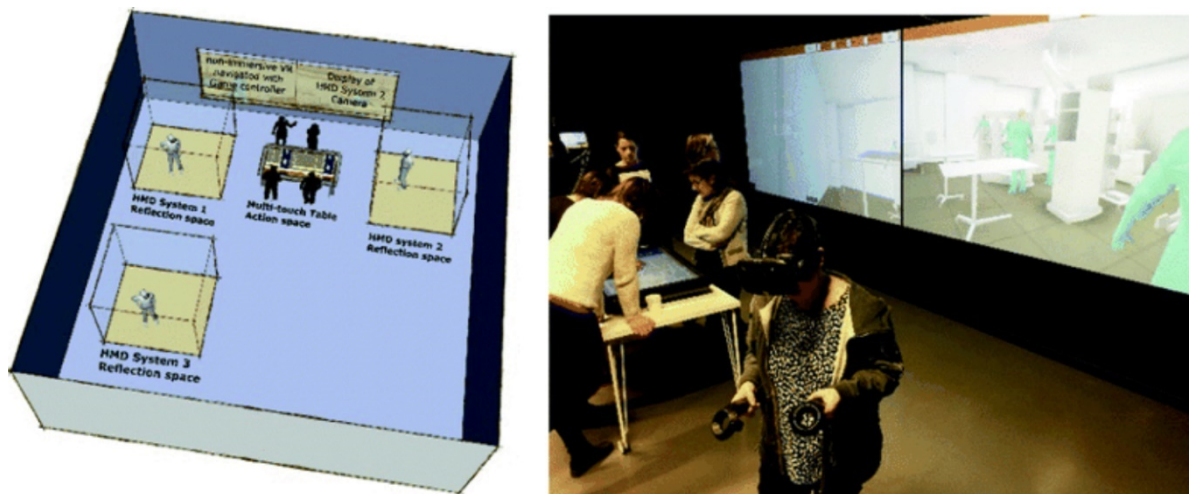


Figure 5: This picture shows the HMD-system set-up during their second workshop which was used together with the multi-touch table and non-immersive VR (Roupé et al., 2018).

4.3.4 BEAst Label

BEAst Label is a standard introduced by the Swedish Construction Industry's Electronic Business Standard to be used for deliveries to construction sites and aims to streamline the internal logistics of a construction site (BEAst, 2020). Packages that are to be sent to a contractor, subcontractor or other operator must be labeled with the BEAst label. The standard has been developed in the SBUF-funded project "More efficient goods supply" where contractors, developer, suppliers and system companies participated in the working group. The label has been tested on a smaller scale in 2013 with very good results. A prerequisite for the labeling is that the contractor sends the order message according to the BEAst Supply Material standard in order for the supplier to have access to the data required for the labeling. One of the important features of the label is the destination field, which shows the delivery location on the construction site in capital letters. The purpose is to ensure that the location information can be read by the truck driver without leaving the truck and a required data shown on these labels is the un-loading place.

BEAst (2020) divide these labels into four versions:

BEAst Label A: intended primarily for pallet goods and applied in two identical copies, one on each side of packages.

BEAst Label B: which is intended to be applied to packages that do not constitute pallet goods and to all underlying packages, e.g. cartons placed on a pallet or placed in another package.

BEAst Label C: constitutes a supplementary table of contents, primarily BEAst Label B, and must never be applied to a package alone.

BEAst Label D: is a product label that complements the manufacturer's own article labeling. This label is optional and can be used if necessary.

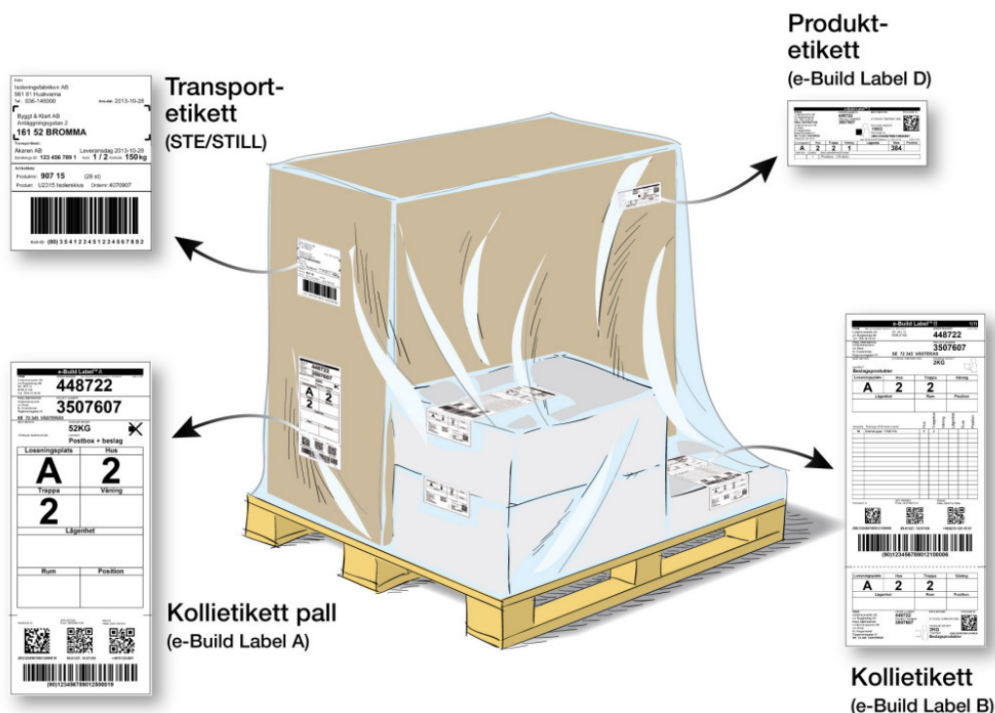


Figure 6: BEAst Labels and their application on different packages (BEAst, n.d.)

4.4 Digital tools on the Construction Site

This chapter briefly describes different digital units and software with the possibility of being used on the construction site for logistics management. A selection of digital units and software is summarized to create a general idea of how they could be used in at the construction site. Further, advanced work packaging is presented as a work set used in construction logistics management.

4.4.1 Digital Units on the Construction Site

Down below in this subsection, some common digital units are described which today are used on the construction site.

4.4.1.1 Tablets

Tablets have increased significantly in use in recent years (Niklasson and Nilsson, 2019). One reason for the increasing use is the thin and flexible design of the tablets and the touch-based operating systems. The tablets vary greatly in performance depending on the model, but the development is fast moving forward. Tablets are available in several brands and with different operating systems, such as iOS, Windows 10 or Android. The different operating systems have different advantages and disadvantages. Almost all tablets are based on special operating systems designed to promote touch-based use (Intel, n.d.). Applications are created to simplify use compared to a regular computer. Newer tablets have high performance, and applications are created to maximize tablet capacity. The natural user interface makes the tablets easy to use and useful in many contexts.

4.4.1.2 BIM kiosk

A BIM kiosk is large portable cabinet on the construction site equipped with a computer with keyboard, mouse and a large monitor (Bråthen and Moum, 2015). The cabinet can be moved within the building as it is portable and usually equipped with wheels. The computer is covered with durable covers to cope with the harsh climate of a construction site. The display should be durable and built for industrial use and can advantageously be equipped with touch function. The computer is equipped with up-to-date software and tools in order to facilitate the daily work and minimize the number of times a supervisor or skilled workers need to walk between the site and the site office.

4.4.1.3 Interactive Whiteboard

An interactive whiteboard is basically a whiteboard equipped with touch function (SmartBoard, 2017). The whiteboard is compatible with all computers and projectors. It can be used as an interactive and practical tool in connection with presentations, discussions and teaching. The basic idea is to combine the traditional whiteboard with the versatility of a computer. With an interactive whiteboard, content can be conveyed quickly and clearly to facilitate understanding. The created work on the board can then be saved and reused if desired.

4.4.2 Software on the Construction Site

The following subsection contains a description of the software company Autodesk and different software developed by them and other companies which are used on the construction sites today.

4.4.2.1 Autodesk

Autodesk is a multinational software company founded in the United States of America in 1982 (Autodesk, 2020a). Autodesk develops products for the architecture, engineering, construction, manufacturing, media, education, and entertainment industries. Their flagship program is AutoCAD and they are a leader in 3D design software. Below are some of their software and platforms used in AEC industry presented.

4.4.2.2 BIM 360

BIM 360 is a platform that connects project team and data from design to construction in real time, supporting informed decision-making and providing predictable profits (Autodesk, 2020c). BIM 360 provides the ability to centralize the project data and the ability to access the information any time in order to track projects and make decisions in the field as well as during the design phase. BIM 360 enables to work on one platform during both design phase and construction phase. It also gives the opportunity to controlled work sharing which enables multidisciplinary teams to co-author shared models, visualize each update, and manage design data throughout the project lifecycle. In BIM 360, the multidisciplinary teams are able to mark any errors or clashes, assign them to the responsible group or person in the same platform in order to have optimized and error free model and drawings.

BIM 360 Field enables project stakeholders to collaborate on checklists, distribute drawings and access mobile 2D and BIM construction documents in the cloud in real time on a laptop or tablet (Autodesk, 2020d). BIM 360 Field's objective is to save time, improve quality and safety, and reduce costs. For example, BIM 360 Field gives the opportunity to create a digital safety inspection checklist to report on compliance, tag and track the building components and enables the user to track progress on the site and create daily reports, all in the same platform.

4.4.2.3 Revit

Revit is a multidisciplinary Building Information Modelling software that provides high quality coordinated designs (Autodesk, 2020f). Revit includes tools for architectural design, MEP and structural design and provide the ability for involved disciplines to use work-sharing i.e. share and save work to the same project. The software allows users to design buildings and structures and their components in 3D, annotate models with 2D drawing elements, and access building information from a database of building models.

4.4.2.4 NavisWorks

Navisworks is a 3D software for reviewing architecture, engineering and construction (AEC) projects provided by Autodesk (Autodesk, 2020e). Navisworks is mainly used to complement 3D design packages, such as Revit and AutoCAD. This software allows the users to open and combine 3D models and supports more than 60 file-formats. Navisworks provides the ability to navigate around the model in real-time and review the model using a set of tools including comments, redlining, viewpoint, and measurements. Navisworks has the ability to combine design and design data into one model and identify collisions and disturbances in the model. Navisworks uses 4D and 5D simulations to gain control over time and costs in the model and interact with model objects to create better simulations.

4.4.2.5 InfraWorks

A Technical Solutions Executive (personal communication, March 11, 2020) from Autodesk describes InfraWorks as a software to plan and design infrastructure projects and site layout in the context of the real-world. The software has the ability to find the site location by GPS coordinates and gives a visualized picture of the surrounding area in the real-world context.

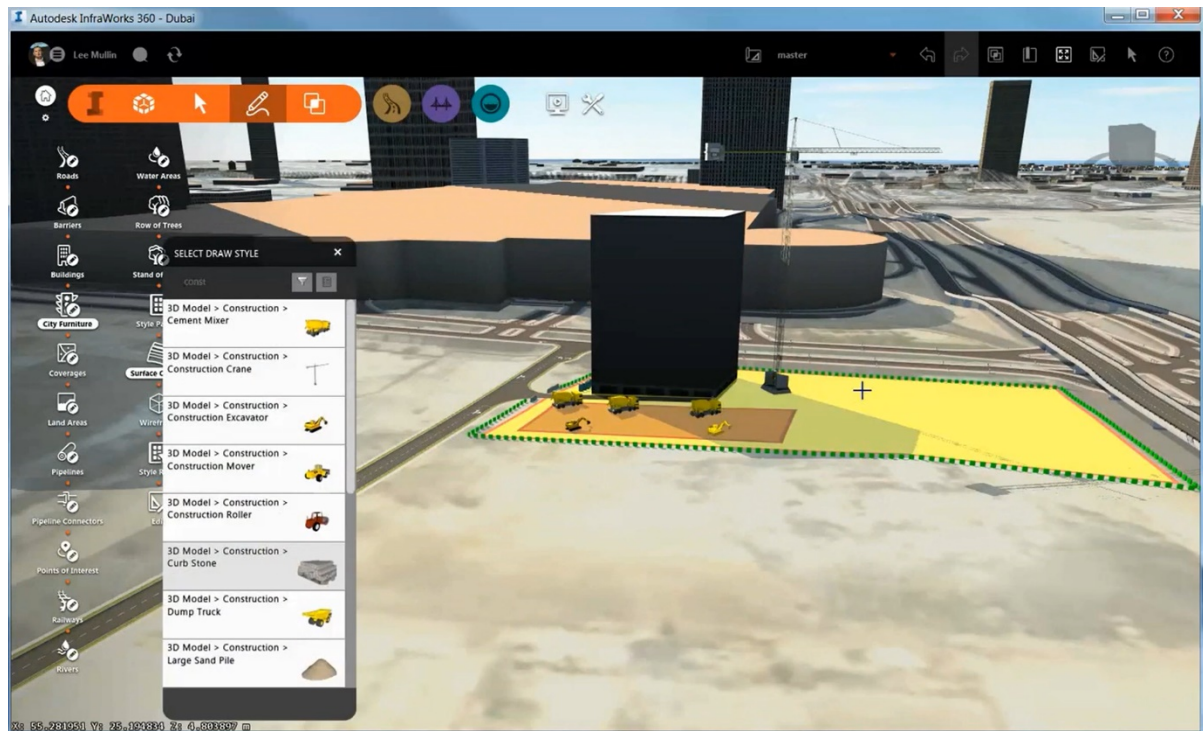


Figure 7: The picture shows the interface of InfraWorks (Mullin, 2016)

The Technical Solutions Executive (personal communication, March 11, 2020) explains user-friendliness in this software and the opportunity to very quickly draw a site-layout and the Construction Logistics Plan (CLP) in 3D. One of the features of InfraWorks is the ability to choose the detail-degree of the model that is created in the software. The software provides the ability of importing IFC-files which means that the user can import the building-model with coordinates created in other software into InfraWorks. Another feature which can help the user to have a more detailed site-layout is the ability of importing point cloud drone-files by the format of fbx to have a more visualized picture of the site.

Another feature of InfraWorks mentioned by the Technical Solutions Executive (personal communication, March 11, 2020) is the ability of creating transport roads in the model and easily drag and drop trucks, cranes etc. in order to plan the CLP. The user can also measure and control different types of uncertainties e.g. turn-radius for a truck that has to turn around a corner on the site.

4.4.2.6 Assemble

Assemble is a cloud-based system acquired by Autodesk and will be integrated into Autodesk's BIM 360 project management platform (Autodesk, 2020b). Assemble is according to a Senior Manager (personal communication, March 11, 2020) at Autodesk system of engagement which combines and unlocks models, drawings, and point clouds. Assemble conditions and organizes

the data and has the ability to connect to other construction systems. Assemble provides the ability to regroup different components and materials by different categories. Assemble provides the ability to use the model for all status information on the delivery which is also connected to BIM360.



Figure 8: Real time status visualization enables to visualize any data in the context of the project model. (Autodesk, 2018)

4.4.2.7 Centiro

Centiro Solutions AB is a leading innovator of cloud-based services for managing product flows in e-commerce, logistics and industry. Regarding construction logistics management Centiro delivers both iLogistics and Centiro Universe. iLogistics is a transport administration system. A transport administration system, or in short, a TA-system, enables & simplifies digital transport bookings. It facilitates communication between transport buyers and transporters and creates the opportunity for both small and large companies and organizations to utilize their transport resources more efficiently through transparent transport chains (Reddy and Kumar, 2018). Centiro Universe is a cloud-based delivery calendar that is used to collect information about incoming deliveries both during planning and execution of a project.

4.4.3 Advanced Work Packaging

A Senior Manager (personal communication, March 11, 2020) at Autodesk describes Advanced work packaging as an overall process flow of all the detailed work packages (CWPs, EWPs, and IWP). It is a planned, executable process that encompasses the work on an engineering, procurement, and construction (EPC) project, beginning with initial planning and continuing through detailed design and construction execution. Advanced work packaging provides the framework for productive and progressive construction and presumes the existence of a construction execution plan. An engineering work package (EWP) is an engineering and procurement deliverable that is used to create construction work packages (CWPs). A construction work package (CWP) defines a logical and manageable division of work. An installation work package (IWP) is the deliverable that enables a construction work.

Traditionally has Advanced Work Packaging (AWP) been not cost effective to deploy on small projects and has been time-taking with high cost to implement. It has also been paper based and very depended on the design system. The Senior Manager (personal communication, March 11, 2020) at Autodesk explain that Autodesk's focus has been to increase the return on WorkFace Planning investment but also to have scalable AWP align processes and workflows and leverage the acquisition to accelerate the Autodesk AWP Platform.

A case study presented by Autodesk (personal communication, March 11, 2020) shows that AWP integration with BIM360 provides in increased productivity and reduced rework. The Senior Manager mentions also how paperless system walkdowns and automated reporting with help of BIM360 Field facilitated the workload on the site and the RFI.

4.5 Implementation of Digitals Tools within the Construction Industry

In this section different obstacles and critical factors of the implementation of digital tools within the construction industry is presented.

4.5.1 User-friendliness

In order to create a good user-friendliness of computers, software and applications, is a good user interface by high importance (Blake, 2010). Research shows the benefits of Natural User Interface (NUI) and explains that a software can be effective for all ages, by being simple to use and easy to learn. NUI is based on a human being's natural movements, movements that has been practiced throughout the life, instead of learning new movements like controlling a mouse pointer. In summary, NUI is based on natural human behaviors such as gesticulating, talking or pointing, which is something most people have good knowledge of, even if they have never used any computer-based program. Tablets and smartphones can be named as examples using NUI, e.g. tablets integrate with information by pressing directly on the desired function with fingers (The Verge, 2013). Through NUI, learning of new "unnecessary" abilities in order to accomplish new complex maneuvers is avoided (Blake, 2010). Complex maneuvers increase cognitive load which leave less space in the brain for the learning process itself but by being able to make use of existing capabilities and abilities, the more space will be available for the actual learning process.

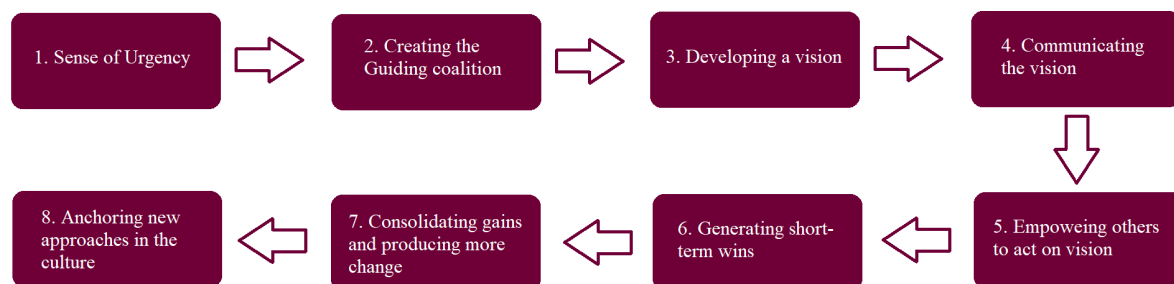
A way to create good user-friendliness suggested by Blake (2010) is to limit the number of functions that can be performed simultaneously. By diversifying functions and futures into large categories instead of having all the features available at once could be named as an example. The desired function can be found by narrowing in the category lists. Anyhow, this method can be considered more difficult than directly getting to the desired function, but it reduces the burden on the brain when less thought is required. However, NUI is an important part of the future development, since its interaction with programs will increase the control, efficiency and joy. An important function, as with all systems, is to always provide easy access to an undo function. This function is important since miss-clicks on the screen may occur in the wrong place or at the wrong time.

4.5.2 Attitude Towards Change

An organizational change or a change in work methods, brings always an imminent risk of insecurity and uncertainty in both management and frontline employees (Wanberg and Banas, 2000). A change from the known to the unknown often causes people to resist the change. Leadership becomes then important to enable the change and success in its implementation. The people who understand the challenges and opportunities often experience the change as something positive while the people who do not understand its benefits, feel outside and oppose the change even more.

Change management and its processes are known as highly debated subjects among researchers (Bommer, Rich and Rubin, 2005). On point of view within the subject which most people agree on is the importance of involvement of all parties in the process. According to Yukl (2005), lack of involvement in decision-making leads to a resist against the change. The opportunity to influence, on the other hand, creates a sense of participation that leads to increased acceptance of the change (Bommer et al., 2005). Anyhow, studies show that people instinctively prioritize their own interests instead of the best interests of the organization which can also be seem as another obstacle within implementing changes to a workplace. Resistance to change can mainly be divided into two categories (Pollak, 2001). The individual resistance which depends on individuals' uncertainty and attitude to changes. The second type of resistance is organizational and means that the changes clashes with the company's organizational culture.

John Kotter (2012) describes an eight stages process of creating major change in order to success with changes in an organization which is shown below.



This picture visualizes Kotter's eight stages of change

4.5.3 Interoperability Barrier

Interoperability barriers are a well-known problem in the architect, engineering and construction (AEC) sector (Grilo and Jardim-Goncalves, 2010). According to Leite et al. (2016), interoperability has been identified as the most important challenge for information modeling in the construction industry. This is mainly because of the high number of different actors and systems that typically are used in the sector together with the dynamics and versatility needed to operate in the AEC sector. Interoperability is defined by Grilo and Jardim-Goncalves (2010) as the ability of information exchange and usage between two or more systems or components. A true interoperability is achieved when internal data can communicate and exchange information with a universal open data model. By reducing duplication of work and reducing the chance of field errors, interoperability in the construction

industry increases the productivity of construction workers (Tibaut, Rebolj and Perc, 2016). The negative cost impact caused by interoperability inefficiency can be divided to 17% in planning phase, 26% during the construction phase and 57% in the facility management. Archimède and Vallespir (2017) divide interoperability barriers into three categories of barriers: conceptual, technological, and organizational. Conceptual barriers involve only informational issues, such as their representation at a high level of abstraction or programming. Technological barriers involve IT issues related to computer use. Organizational barriers involve human issues such as responsibilities, authority, organizational structure and management.

BuildingSMART, formerly International Alliance for Interoperability (AIA) has introduced an approach called OpenBIM based on open standards and workflows in order to increase interoperability (Djuedja, Karray, Foguem, Magniont and Abanda, 2019). Industry Foundation Classes (IFC) which is an object-oriented standardized terminology designed to facilitate data exchange between BIM tools is included in this approach. OpenBIM is intended to avoid different interpretations and mistakes in order to work together without errors.

4.6 Work Environment Safety

The construction industry is considered as one of the most dangerous industries in Sweden to work in according to the Swedish Work Environment Authority (2020). During the recent five years has the construction industry been ranked at third place when it comes to dangerous workplaces in Sweden. Although an improvement with this issue can be seen since the industry was during 2019 ranked at the fourth place after health care-, production- and transport industry and had 5 percent less accidents compared to 2018. However, it is worthy to mention the fact that work environment in the construction industry is different compared to other industries. It is mainly because the work environment is temporary since the work is done in different projects with different conditions but also because of constantly change of the construction site. Involvement of different types of subcontractors, heavy machines and heavy components increases the risk of accident and may lead to an unsafe workplace.

In international comparisons, Sweden is still below the average when it comes to workplace accidents. Comparing accident rates with other EU countries, Sweden is far below average. Figures from the EU statistics agency Eurostat (2017) show, among other things, that for the construction and service sector, the frequency was 1 927 accidents (without fatal outcome) per 100,000 employees in EU15 countries in 2014. Meanwhile the corresponding figure in Sweden was 745 accidents per 100,000 employees. For fatal accidents, the corresponding figures were 2.08 in EU15 compared to 1.26 in Sweden.

4.6.1 Case of Accident with a Fatal Outcome

Movement of heavy vehicles and heavy goods are two major causes for fatal accidents on the construction site (personal communication, December 4, 2019). Therefore, the planning and monitoring of logistics operation has a huge impact on the safety of the construction site. Further in this subsection, a case will be presented where poor planning and monitoring of logistics were one of many factors that led to an accident with a fatal outcome.

One of the largest contractors in Sweden had outsourced the delivery and assembly of a steel framework to a subcontractor (personal communication, December 4, 2019). The sub-

contractor (1) had in turn hired another sub-contractor (2) to assemble the framework on site. The sub-contractor (1) later discovered some defects on some of the frameworks and then hired another sub-contractor (3) to repair the frameworks including transport to and from the site, its agreed that the framework should be delivered latest by Friday that week.

On the Thursday afternoon at 4:30 pm the sub-contractor (3) sends an email with the information that the framework is now on its way towards the construction site. None of the receivers of the email were still at site at this time, they had all left for the day and the information did never reach the site manager. During the transport the chauffeur contact a supervisor from sub-contractor (2) to inform that the deliver was delayed. The supervisor from the sub-contractor (2) was not at the site and did not pass the information further to neither the contractor nor other personnel at sub-contractor (2).

Around 5 pm, the construction site was hit by a power outage which led to that the construction crane became out of function. Just before 6 pm the contractor and the sub-contractor (2) decides to stop the work for the day. Three employees at sub-contractor (2) stay at the site to prepare for tomorrow's work while the rest go home for the day. When the transport arrives at 6 pm the chauffeur calls the same supervisor at sub-contractor (2) and informs him/her that the site seems to be empty and will unload the framework him/her-self.

The chauffeur enters the construction site with a gate code assigned at an earlier time. Once at the site, the driver is met by employees from sub-contractor (2). The unloading takes place with the truck crane which is controlled by a remote control. This is not in accordance with the agreed unloading method that states that the construction crane at the site should be used for all the unloading of material and goods. One of the employees of sub-contractor (2) takes the loading straps that are normally used for the construction crane on the site and climbs onto the truck. The employee connects the straps to each beam and then onto the hook. The beam weighs about 800 kg and is 6 meters long. The employee remains on the truck's surface while the lifting has started. Since the pillars around the truck's surface have not been removed, the beams must be lifted over them. About one and a half meters above the truck's surface, the beam turns and then one strap loosens from the hook. One end of the beam falls and hits the employee that stands on the truck's surface. This results in a deadly outcome.

This fatal accident was a result of several flaws building upon each other. The accident was investigated by the contractor and the underlying causes are identified and presented below.

Direct causes of the accident:

- The crane hook was defective, it was stretched out so that the safety catch could not handle the load.
- The straps were too short. The angle between the beam and the strap was less than 30 degrees, whereas at least 45 degrees is required for the lift to be safe.

Contributing causes:

- The work preparation for the work describes that this type of material should be unloaded with the help of the construction crane at the site. This work preparation was not followed at the time of the accident.
- The code for the gate had been distributed to transporter by sub-contractors. The driver could therefore gain access to the site without registering.
- The management of the contractor was not aware of the oncoming delivery. Therefore, they could not plan and adapt to the new conditions.
- The sub-contractor's (1) site organization was not adapted to this extra workload of taking care of another sub-contractor which increased the risk.

5 Empirical part

In order to gain a deeper understanding of digitalization in logistics management and its current status, as well as the problems that exist, interviews with both personnel in Skanska and also external partners in the subject have been conducted. A list of interviewees and the findings of the interviews are presented in this chapter.

5.1 Interviewees

The interviewees consisted of the following official at Skanska:

- Logistics Coordinator (Skanska)
- Logistics Manager (Skanska)
- Production Manager (Skanska)
- Construction Supervisor 1 (Skanska)
- Construction Supervisor 2 (Skanska)
- Digital Block Manager (Skanska)
- Logistics Engineer (Skanska)
- Contact person (DHL)
- Senior Manager (Autodesk)
- Technical Solutions Executive (Autodesk)

A more profound description of the interviewees is found in subsection 2.3.2 in the Method chapter. The Logistics Coordinator, the Production Manager and the Digital Block Manager was located at a development project of a large commercial building. The project had a very limited area and were today using a Construction Consolidation Centre. The Construction Supervisor 1 and Construction Supervisor 2 were located at a larger residential housing project. The Logistics Manager were located at a project developing a hospital.

5.2 Logistics

Three different construction sites were visited and considered in this study to get an understanding of how the case company Skanska is working with logistics management on their construction sites today. The construction sites consisted of three different types of development projects, hospital projects, a large commercial building and residential buildings project.

The design of the construction site was structured differently on each site depending on the individual characteristics of the project and the environment around the site. The surrounding area around the construction site deeply affect the planning of logistics and the transportation flow to, from and within the construction site. Two of the sites that were studied did only had the possibility for one gate while other sites had the possibility to have two or three gates. According to the Logistics Manager, a construction site with only one gate is problematic since the transports must either turn around inside the construction site or reverse on their way out. Both alternatives are preferred to be avoided as far as possible according to both the Logistics Coordinator and the Logistics Manager due to the increased safety risks and interruptions on the construction site.

The planning of construction site's design is commonly done by an 2D Construction Logistics Plan (CLP) on most of the projects. The demand for a more innovative tool with better visualization ability is different among different construction sites. The Logistics Coordinator and others that are working with a project with more space inside the construction site are pleased with the 2D Construction Logistics Plan available today. The Logistics Manager and the Production Manager, on the other hand, that had a very space-limited site felt a need for a tool that enable a better visualization for planning the Construction Logistics Plan than the existing 2D tool. The Digital Block Manager has tried to visualize the CLP in 3D with already existing digital tools at the site, such as Revit and wishes that he had the opportunity to work more in 3D for the planning av CLP with better suitable digital tools.

5.2.1 Construction Consolidation Center

Due to the lack of space on the construction site the Logistics Manager states the need of a Construction Consolidation Center (CCC). The Production Manager agrees upon the logistics manager's opinion that a CCC almost is a must for a construction site with a very limited space. This due to the need of being in control of deliveries arrival time. The Production Manager says that time-specific delivers are an alternative to the CCC. One of the disadvantages stated by the Production Manager for time-specific delivers is not being in control of the delivers. This means that they will not be able to check every order before shipment towards the site, they will then have to trust another middle hand instead of owning this control by themselves.

The material will normally arrive at the CCC about one to two weeks before it is needed on the construction site. At the CCC, the material will be repackaged, suitable for the construction site and then called off through a dialog between the CCC and construction site. In this way, the construction site can be in control of that every delivery is packed exactly in the way they prefer and include everything needed on the site. Both the Logistics Manager and Production Manager state that with this method, the control over the transport flow into the construction site will be strengthen. They state the importance of this control due to the minimal space and lack of ability to receive unexpected transports on their current construction site.

5.2.2 Deliveries to the Site

The Construction Supervisor 1 and 2 mention another alternative to time-specific delivers and the CCC concept, which is to coordinate the deliveries with help of logistics companies such as DHL. Both the Construction Supervisor 1 and 2 as well as the Digital Block Manager has positive experience from this type of logistics delivery method. The disadvantage of this method mentioned by them is the amount of information that must be handled manually to book this kind of transports. Which according to them makes the human factor a big part of in whether the delivery will be successful or not. All these three mentioned alternatives to achieve more control over deliveries time span are expensive according to the interviewees. The Production Manager along with other interviewees consider the economical factor as the main reason why these three alternatives are not widely used in projects. Which is in turn the reason behind why the officials do not have a lot of experience using these methods.

The Digital Block Manager had booked time-specific deliveries in his last project which was booked for an extra charge. He states that he was very pleased with this type of delivery and believes that it was worth the extra charge. He explains that he either had to pay extra for the carrier to wait outside the site or for the lull driver to wait until the delivery had arrived.

According to the Digital Block Manager, these time-specific deliveries enabled to cut extra expenses and reduced the stress level at work.

Both the Construction Supervisors 1 and 2 experience that there is an unnecessary large number of small shipments to the construction site. They pointed out two mainly causes behind this. First, poor planning of material needs such as screws, plasterboard etc., both by Skanska and the sub-contractors. They state that this problem is bigger among the sub-contractors. This is mainly because they are not used to plan the need of their material more than a few days in front. The Construction Supervisors 1 and 2 explain that this is mainly because Sub-contractors have not needed to do so traditionally, and they are almost always able to get their material one day after an order. The other cause is Skanska's purchase system IBX. IBX is not built in a favorable way to minimize the amount of shipments, more about this in section 5.4 of Digital tools down below.

A new delivery method within logistics management mentioned in the interviews is barracks with Q-lock system on the construction site. According to the Construction Supervisor 1 and 2, suppliers have the opportunity to deliver the goods and materials and leave them in the barracks. Suppliers can open the barracks by an app called Q-lock without entering the site. They also explain that this method is mainly used for the small and mid-sized deliveries. The Logistics Coordinator claims that not every carrier has access to the Q-lock system and cannot unlock the barracks. Which will in turn create a demand on the Logistics Coordinator to receive the delivery manually anyway.

5.2.3 Challenges on the Site

The biggest challenge stated by the Logistics Manager is having every delivery to arrive at the designated time since they have a crowded site and only the ability to have three trucks on the site at the same time. He also states that there is no place for the trucks to park outside the site and wait which makes this challenge even harder. Both the Logistics Coordinator and the Logistics Manager agree on that they desire better information about what time a transport will arrive at the construction site. They state that the precision of a delivery's arrival time today on what day it arrives and not a specific time of the day. The Construction Supervisor 1 and 2 state that at best they know if a delivery will arrive in the morning or afternoon. Both the Logistics Manager and the Logistics Coordinator mention that transports from abroad are the transports with highest uncertainty about the time of arrival. The Logistics Coordinator believes that poor information to the chauffeur and lack of communication between the intermediaries is one reason behind it, together with the long distance of travel and all the uncertainties on the way.

The Logistics Coordinator states that one of the biggest challenges with the logistics management on the construction site is the lack of communication between the several number of different intermediaries such as carriers, suppliers, and purchasers. The lack of communication is often because of involvement of the high number of sub-contractors for one delivery which causes the loss of information down the line. The Logistics Manager considers higher communication demand already from the purchasing phase as a solution to the issue named above. He states that a better communication between the different intermediaries can let them have all the information about the deliveries which will facilitate the operating phase. The Logistics Coordinator mentions that problem in the communication can also be because of language barriers, information loss due to high number of intermediaries involved in one delivery.

Another issue highlighted by both the Logistics Manager and the Logistics Coordinator is the lack of space on the construction site. The Logistics Manager points out that the lack of space on the construction site makes the share of information and communication very critical since there is a no possibility for site-storage in some projects. The Logistics Coordinator mentions that the Lack of space combined with unplanned deliveries increases the safety risk on the site since the trucks and the workers will share the same work areas on the site. Also, the Construction Supervisor 1 and 2 mention that unplanned and unforeseen works that come between the planned work tasks will make logistics even more difficult.

Another obstacle mentioned by the Construction Supervisor 1 and 2 as well as the Digital Block Manager is the poor planning for the material consumption on the construction site. According to them, the skilled workers and the sub-contractor are not used to plan their material consumption in advance. Traditionally, they are used to make an order when they are out of material and have been able to get the material a day after. The Digital Block Manager states that it is a must to increase the communication and have better control of the material consumption to be able to improve the plan of material flows.

The Digital Block Manager explains the negative impact that a large space on the construction site may have on the logistics management. He claims that a larger space on the construction site it not equal to better logistics management. Storing material on the site on the construction site creates another step in the supply chain, a step that is not value-creating. He states that by adding another non value-creating step to the supply chain is not the optimal solution even when site storage is available. He thinks that it is a fail in the planning and the operation by moving a package twice. Therefore, the same supply chain process should be used regardless if there is possible to store material at the construction site or not to maximize the value-creation in the process.

5.2.4 Efficient Flow

All the interviewees believe that planning is the key to achieve an efficient flow of material on the construction. The Logistics Coordinator mentions that it is by high importance to have the places for unloading clear and the transports routes planned early in the projects. Another important factor is to set a limit for the number of large deliveries in the same day, this is important to avoid a cue of transports into the construction site. The Construction Supervisor 1 and 2 believe also that planning is the most import factor to a more efficient flow. They think that there is a lot of potential for improvement in the planning of material consumption. Today there are many small deliveries being delivered at different time to the site. This is due to poor planning of material consumption by both Skanska and their sub-contractors.

The Logistics Manager and the Construction Supervisor 1 and 2 along with the Digital Block Manager enlighten the importance of communication to achieve an efficient and even flow of material to the site. This is extra important because of the high number of involvements of sub-contractors for one delivery. The Production Manager mentions having a delivery calendar as an important factor to an efficient delivery flow to the site, the calendar enhances the knowledge and overview of what time and day the different deliveries will arrive. He also points out the importance of following the delivery calendar and sticking to the plan as another major factor to achieve an efficient and even flow.

5.3 Work Environment Safety

All the interviewees point out the unloading phase as the riskiest logistics work moment on the construction site. According to the Logistics Manager the biggest challenge to a safe workplace is to have the sub-contractor aware of the importance of a safe workplace. This challenge according to him is getting bigger since Skanska outsource the work more and more in their projects. The Production Manager also think getting the sub-contractor to follow Skanska's work set, and work align with them as the biggest challenge to a safe workplace for Skanska today.

The Construction Supervisor 1 and 2 point out good logistics management as the basis for a safe workplace. They believe that safety goes hand in hand with the stress level of the workers on the site. With more time spent on a work task, the more thoughtful and better planning can be achieved. Which according to them can eliminate the stress factor. They believe that stress impairs logistics management and the safety on the site. The Construction Supervisor 1 and 2 and the Digital Block Manager point out stress as a key factor that often comes up with unplanned deliveries. According to them planning and having the time to prevent risks will minimize the stress on the site. They state that logistics is about anticipation and if the planning goes well, safety will also increase.

5.4 Digital Tools

This section contains the empirical data regarding the digital tools used on the construction site today. Further in this section are the challenges to a more digitized logistics management described and the thoughts on the future.

5.4.1 Digital Tools Used within Logistics Management Today

All visited projects except the residential buildings project did use Centiro Universe in their daily logistics work which is a cloud-based delivery calendar. Logistics Manager explains that the information about deliveries are registered in this tool. The containing information includes the unloading place, delivery time, delivery slot time and information about the person responsible for receiving the delivery. The Logistics Manager can authorize anyone with different permissions to preliminary book a delivery in this tool. Later, the Logistics Manager can approve the booking if it fits the calendar and the logistics flow. The purpose of using this cloud-based tool in a project is to enable everyone involved in the project such as sub-contractors to book a time slot for their deliveries in the same platform. The Logistics Manager states that this can in turn facilitate the daily work and improve the planning work since the communication and information takes place in the same platform for the entire project.

Another digital tool named by the Logistics Manager and the Digital Block Manager is Coordination which they do not use in their project today. Coordination is a tool to register information about the delivered packages on the site or the consolidation center. This tool provides also the ability to register pictures of the delivered packages. This will in turn help the Logistics Manager and others to easily see what is delivered in order to make sure that the material needed for a work task is in place and available on the site.

Construction Supervisor 1 and Construction Supervisor 2 are both very positive to a more digitized work set and prefer to work with digital tools instead of the traditional way of

working. Despite their attitude towards a more digitized daily work, they have chosen to stop working with the digital delivery calendar, Centiro Universe. They used to work in this system from the start of the project but since it was not followed as it was thought, they chose instead to plan deliveries on a whiteboard placed in the project office. They mention the lack of information shared in the system by sub-contractors as one of the main reasons behind stop using Centiro Universe. The sub-contractors did not shared information in this digital delivery calendar mainly because of the lack of knowledge about the system but also because they could not see a value by working in this tool. Another reason mentioned by Construction Supervisor 1 and Construction Supervisor 2 and the Digital Block Manager is the heavy workload caused by Centiro's delivery calendar. The Construction Supervisor 1 and 2 did not had the knowledge to use the system's ability to communicate with the supplier's system. Therefore, they had to share all the information manually which was very time-consuming.

Another digital tool mentioned in the interviews is IBX which is a digital procurement system used among different companies and industries including Skanska. IBX provides the ability to search and purchase different types of goods and materials from different suppliers in the same platform. Construction Supervisor 1 and Construction Supervisor 2 are both dissatisfied with IBX due to different limitations in the system. One of the mentioned limitations by Construction Supervisor 1 and Construction Supervisor 2 is misses in information about different supplier's inventory. IBX can give several small deliveries instead of actually getting all the material in the same delivery. For example, a search for 1000 plasterboard can give a result of 600 plasterboard available from supplier A and 400 plasterboard from supplier B, while one of them have 1000 plasterboard in their inventory. This will in turn result in more small deliveries instead of one delivery. According to Construction Supervisor 1 and Construction Supervisor 2, an increased number of deliveries results in a heavier workload. They think that this coordination should already exist between the IBX system sand the suppliers in order to avoid many small deliveries.

5.4.2 Challenges

One of the main challenges, named in the interviews, to a more digitized logistics management is the lack of user-friendliness in the digital tools used today. The Production Manager states that there are a lot of features in a tool which makes it difficult to navigate in the tool and hard to work in. Construction Supervisor 1 and Construction Supervisor 2 also complain about the lack of user-friendliness in today's digital tools. They mention involvement of both the young generation and the older generation on the site as a basis for importance of user-friendliness in digital tools. This is because of not everyone is used to work with computers and digital tools on the site and the tool should fit everybody's computer knowledge and experience. However, the Production Manager mentions that the user-friendliness has gotten better with the years and he hope for more user-friendliness in the future digital tools.

Another challenge mentioned in all the interviews is the time-taking learning process of new digital tools. The learning process of new digital tools takes time and the people on the construction site are already short of time in the production. The Production Manager considers the lack of time for learning new tools as one of the main obstacles to a more digitized logistics management. He thinks that people should get a chance to learn before using the tool on the site. The logistics Manager experiences that implementation of new digital tools becomes often as a pilot project and they do not have the time in the project to learn these new tools. He also

like the Production Manager thinks that they should be getting time to learn the tools before using them in a project.

All the interviewees consider the high number of digital tools as another main challenge. The Production Manager points out that it is inefficient to constantly implement new digital tools which in turn means a change of the work sets. This is again a time-consuming process and is difficult to get everyone on board for the change. Both the Logistics Manager and the Logistics Coordinator consider the large variety of different digital tools as a reason for confusion among the users which can make them to lose the interest for working more digitized. Both the Construction Supervisor 1 and 2 states that there is no automatic communication between the different tools which requires him to manually coordinate the information between the different systems.

Another challenge discovered during observation study was regarding the pricing of the digital tools and the economic initiative when choosing what tool to use. When Skanska sign a contract with a certain enterprise for the use of their digital tool, they also must put a lot of resources into learning and implementing the new software in the organization. This create a dependency by Skanska for the software delivered by the enterprise. The enterprise can then make use of this dependency and increase the price of the software which normally is paid by a monthly or yearly fee. This in turn can force Skanska to change the supplier of the software due to economic initiative, then Skanska once again must learn and implement a new software in their organization. Skanska's collaboration and partnership with Autodesk, the software supplier, can be one solution towards this challenge of constantly changing the digital tools due to economic aspects.

Another main issue named in the interviews is the lack of shared information in the digital tools. The Logistics Coordinator states that the tool cannot be better than the shared information available in it. The Logistics Manager talks about the lack of will in working more digitized among the people on the construction site which is the main reason behind the lack of information in digital platform. The Construction Supervisor 1 and 2 believe that a lot of people involved in a project do not see the value by working in digital tools. The production Manager thinks different interests specially the lack of interest in working more digitized by the older generation is the main reason behind this challenge. Although, he sees a bright future since the older generation is retiring and the new generation is taking more place in the industry.

A barrier named by the Digital Block Manager is the interoperability barrier between different digital tools today. He claims that different files have their own file formats and must be converted to use them in the same tool which is a time-taking process that demand manual handling. An issue he has today is connected to the 3D CLP since the files from the drone has to convert several times to get it in the planning tool. He wishes to have raw material in a standard format which can be imported to the desired tool directly.

5.4.3 Future

Even if the interviewees have different opinions on the future need for digital tools, they all agree on having more up to dated tools with simplified interfaces. The Logistics Manager and the Digital Block Manager see though a need for a digital system to register the delivered packages on the construction site. He mentions the opportunity to scan a bar-code or a QR-code with a PDA and have the scanned information available and shared in a system would

facilitate their daily work. Having information such as the package's content would help the contractor and sub-contractor to see what is delivered in order to make sure that the material needed for a work task is in place and available on the site.

The Logistics Coordinator prefer to upgrade the already existing tools instead of implementing new tools otherwise he is already satisfied with the degree of today's digitalization. He does not feel any need for new digital tools. The Logistics Manager, on the other hand has another view on this subject. He thinks that to some extent it is enough with just upgrading existing tools, but he feels a need for new tools as well in order to simplify the coordination related to logistics. The important feature of future digital tools according to Construction Supervisor 1 and 2 is to have a tool where everyone can feel a benefit of using it. They also look forward to having more industry-organized tools instead of having a high number of different digital tools.

The Digital Block Manager consider a need for order tracking today. He wishes to have a kind of tracking and confirmation for an order from the they it is ordered until it is delivered in a system. It would in turn enable them to track an order and see what is happening in order to check the error and plan for a time-specific delivery.

5.5 External View

In this section an external view from outside of the projects is presented. The interviewees in this part were central officials at Skanska, Autodesk and DHL. This round of interviews provided in another perspective of the identified issues and solutions.

5.5.1 Logistics

The logistics engineer who works centrally in Skanska with logistics management points out during the interview that the logistics management is handled differently in different projects since these operational choices is done in the project. He mentions the lack of central guidelines and demands on the projects as of the main contributing factor to a non-consistent way of working.

One of the solutions mentioned by the logistics engineer to the problem of too many small deliveries is Co-loading and delivery. The Co-loading and delivery mean that Skanska and the sub-contractors plan their logistics and deliveries together in order to get their materials in the one and same delivery. This is one of the challenges that they are trying to solve at Citygate project already in the procurement phase. The solution is to have the sub-contractors to join from very early stages to get them involved with the logistics management already in the planning and procurement. This creates a structure and provides the opportunity to Co-load and deliver the materials in order to reduce the number of deliveries. Co-loading and delivery are according to the logistics engineer a very efficient concept for keeping track of deliveries since one delivery replaces several small deliveries. He points out that most projects in Sweden do not use the concept of Co-loading and delivery, this is due to several reasons. He mentions culture as one of these reasons but also the fact that the value created by this concept is not yet proven and its benefits are not measured.

5.5.2 Digital Tools

The central logistics engineer at Skanska had a positive attitude towards digitalization. He believes that digitalization has a large part of the efficiency improvement in the logistics management work on the construction site in the future. He stated that the idea of using digital tools in the projects is to cut costs and time in production using the various tools and planning. The logistics engineer mentions that the delivery calendar, Centiro Universe is an efficient digital tool for the final delivery planning. But in order to utilize the benefits of the digital delivery calendar, it is required to plan from the early stages of procurement with sub-contractors as well as within Skanska.

The logistics engineer identifies three mainly obstacles in order to utilize digital tools within logistics management efficiently. First, he points out the attitude towards digitalization within the older generation who executed projects in many years without these digital tools and do not see the benefit of using these tools. Secondly, he mentions the lack of research that measures the time and cost saved by using these digital tools. He believes that there is a need for verified connection between using digital tools and the costs and time saved to make a change in the attitude towards working more digitalized. He experiences in the projects today that the personnel find the using of these digital tools as one extra task to do instead of one task that create better conditions for the work ahead. Thirdly, he points out the lack of central requirements and guideline regarding a standardized digital work-set. Today he experiences a large difference in work-set between different projects. He believes that a more standardized and structured way of working with logistics management, both regarding the process and the digital tools is needed in order to increase the efficiency. This places both demands on Skanska and their way of working with logistics management but will also require Skanska to put greater demand on their sub-contractors already in the early stages in the procurement phase.

The contact person from the DHL claims that they do not deliver packages to the barracks today since there is no lock system standard within the industry to access the barracks. DHL's contact person claims that they cannot keep track of all the different lock systems in the industry in order to unlock the barracks to deliver a package. The logistics engineer explains this issue in more details. He explains that both contractors and suppliers such as Derome, Ahlsell and Hilti and the have their own barracks delivery solution with different lock systems which requires different apps in order to access the barracks. DHL refuses then to use this delivery method until an industry standard solution is achieved.

The logistics engineer mentions the opportunity to follow an order in the delivery calendar, Centiro Universe, if the shipment is handled through DHL. Orders that are procured with other shipment companies than DHL is not available to follow for the personnel at Skanska today, unless they manually search for the shipment ID on respective shipment company's webpage. The reason why DHL provides this feature is because DHL has a collaboration with Skanska which enables DHL to access Skanska's TA-system, iLogistics. iLogistics is a TA-system developed by Centiro which enables the suppliers to book a DHL delivery for Skanska's orders directly in this system. The order information is automatically transferred into iLogistics if the order is made correctly in one of Skanska's digital purchase system, IBX, Fusion or Spik. A URL-link is created in the digital purchase system when an order is placed. This URL-link can be copied to the delivery calendar, Centiro Universe which enables the users on the

construction site to see the order updates and track the shipment directly from the delivery calendar, Centiro Universe.

The logistics engineer points out that a high percentage of the more complex and larger orders are placed via e-mail or telephone instead of Skanska's digital purchase system. This is since the personnel on site find it complicated and complex to enter in larger and complex orders into these systems. Therefore, it is common among the personnel to make these types of orders by phone or email instead. Further, this leads to a loss of information in the TA-system, iLogistics and further on a loss of information in the supply chain and loss of order tracking through the delivery calendar.

Package and delivery labeling is an issue that the logistics engineer mentions during the interview. He mentions the standard BEAst Label which according to him is not working very well in operation. The suppliers' business system does not have all the data required to fulfill that template which means that package labeling is still a concern. With this, you can scan different information from that label.

6 Analysis

The following chapter contains an analysis of the literature studies and interviews conducted. This is built up to answer the research questions that the report poses. The analysis begins with a picture of the logistics management today on the construction site and the underlying causes. Then, the problems that exist and possible solutions to address them are analyzed using digitalization as a guideline. Later on, the obstacles and barriers founded in the empirical study are analyzed and possible solutions to overcome them are presented.

6.1 Logistics

In this section, the empirical data and the background study is analyzed and compared. The analysis and comparison begin with identified challenges with deliveries to the construction site and continues with an analysis of Arbulu and Ballard's (2004) strategy and lean supply systems.

6.1.1 Not On-Time Deliveries

According to the empirical findings, one of the biggest problems within the logistics management today is the existing uncertainty about arrival time of the deliveries. These not on-time deliveries do not meet the seven Rs concept of Storhagen (2011), presented in section 4.1, which result in inefficiencies and unproductivity of logistics management on the construction site. This problem is according to the empirical study caused due to poor communication, involvement of many intermediates and information loss in the supply chain.

Since there are many intermediates involved in a delivery, the communication becomes highly important in order to pass down the information correctly in line. The high involvement of human factor and lack of interrelated digital communication system between the different intermediates, cause poor communication, misinterpretation and loss of information. By other words, the information transfers as in the Chinese Whispers. The Just-In-Time concept of the Lean presented in subsection 4.2.1 intends that the information flow should run smoothly throughout the line in order to maximize the benefit while minimizing the waste.

In order to fulfill the Just-In-Time concept of Lean, the information should pass smoothly down the line without any loss. This requires less manual information handling and less information exchange by the people involved since there is a risk for information loss due to the human factor. A possible solution to solve this problem is to have more interrelated communication systems between the different intermediates. The information will then pass down the line automatically by the system which will increase the dependency on the digital systems and eliminate the human factor in the line. This interrelated system will provide in better connection between Skanska's communication system and logistics companies' communication system which can already be seen with deliveries by DHL that Skanska has a close cooperation with.

Another solution to avoid the problem of not on-time deliveries is the Construction Consolidation Centre (CCC) concept. The deliveries from the suppliers can be delivered to a CCC, a time before its need at the site. Different deliveries can be assembled together at the CCC and shipped to the construction site at a designated time. Since the assembly packages are now sent from the CCC, better process control and monitoring can be gained. The concept of CCC and its advantages will be analyzed later in subsection 6.1.4.

6.1.2 Arrival Time of a Delivery

An aspect raised in the empirical study is the problem of not knowing the arrival time of a delivery. This poor delivery process monitoring, and poor status update can be mentioned as the lack of tracking and monitoring ability. As mentioned in the prior headline 6.1.1; loss of information, poor communication and high number of intermediates are the reasons behind problems of delivery time. A possible solution to this problem is GPS-tracking of a delivery. This can for example be done by an app developed by the help of Transport Tracker provided by Google. The objective of this app is to enable monitoring a delivery by the responsible officials to better plan the unloading processes on the site. The app captures the location of the vehicles and stores it in a Firebase Realtime Database. A map built with the Maps JavaScript API will then provide real-time visibility of the vehicles, routes and schedules. The arrival time can be estimated based on the traffic data in the Google Maps. A suggested feature of this app is to send notifications to the officials in charge of the delivery in advance in order to facilitate planning for the arriving and unloading process.

In the existing non-consistent way of working by the carriers, different carriers contact the officials in charge of the delivery in different ways. Some of them choose to contact the responsible officials by a phone call a short time before their arrival, while other do not alert until they have arrived at the gate. By having the app which can automatically alert the person in charge at a specific time before the estimated arrival time based on the traffic status with the help of Google Maps traffic data, a consistent way of working can be applied. By help of this app, the person in charge knows in advance the status of a delivery and can better plan the unloading of the delivery.

However, this solution will create another digital tool which will increase the number of digital tools used on the site which is already an issue today. This app could be connected to the delivery calendar Centiro Universe. The monitoring and status updating will then take place in the delivery calendar and the responsible personnel will then be notified through the delivery calendar. Here would an app version of the Centiro Universe be useful facilitate the work process.

Another solution is to use time-specific deliveries which costs more but are more accurate since it is already procured which time the delivery will arrive. In this case the personnel on site will be able to order the lull or other needed services for the unloading on a specific time. This way enables to save money by avoid paying for the waiting time for either the lull driver or the transport driver. Another advantage of this time-specific deliveries is the ability to have the planned machines and equipment in order to safely unload the materials and packages. However, it is important to mention that these time-specific deliveries cost more than ordinary deliveries.

6.1.3 High Number of Small Deliveries

Another problem found in the empirical study is the unnecessarily high number of small deliveries delivered at the site. Receiving a delivery requires planning in advance which is a time-taking process. Receiving a delivery itself is also a time-taking process which must be done by a responsible official on the site. This will in turn interrupt hers/his work and create inefficiencies on the site. This is partly because of the poor existing purchase system IBX. An improvement in the purchasing system and a higher level of the system's communication with

the suppliers' system could reduce the amount of small deliveries. This will in turn create a swift even flow on the site since the number of deliveries and the lead time are reduced.

One of the other reasons behind the high number of small deliveries has been identified as poor material consumption planning which goes hand in hand with the traditional way of working and the culture on the construction site. According to the interviewees, the workers are not used to plan the material consumption in advance since they are able to make an order anytime and have the material delivered in many cases the day after. A change in the work set is needed here which can be applied by the help of Kotter's eight step of change management. Higher demands from the officials on both the skilled workers and the sub-contractor could also be a solution to this problem which can be used as a basis to implementation of Kotter's eight steps. Here is decision made from the top, but the engagement and the implementation start from the front line of the production.

Another action to reduce the high number of small deliveries is Co-loading and delivery which was mentioned by the Logistics Engineer. This solution requires close cooperation between the contractor and sub-contractors and involvement of both parties within the logistics management already in the planning and procurement stages. In order to success with this action and be able to execute this concept, a high focus must be placed on planning generally but also material consumption planning. This requires a change in culture, the existing working methods and procurement methods which can be applied by Kotter's eight steps of change as mentioned above. As the Logistics Engineer mentioned in the interview, there is a need to prove and measure the benefits and value gained by this method in order to get the management to act and create clear guidelines and requirements regarding this. It is worthy to mention that a side-benefit gained by this method is the increased ability of tracking and status updating of the delivery since the number of deliveries will be reduced and the personnel on the construction site will have to deal with fewer deliveries.

Another solution to this problem among with time-related delivery issues is using a Construction Consolidation Centre (CCC). The small deliveries are delivered to the CCC and assembled together at the CCC. Thereafter can the assembly packages be pulled to the construction site and delivered to the site. This concept will make a swift even flow of deliveries to the site. However, this concept will not solve the problem thoroughly but just displace the problem to a new intermediary in the supply line which can be recognized as a workaround. This displace which result in an extra delivery from the CCC to the site, will according to the Swift Even Flow theory of Lean considers as a non-value creating process. On the other hand, not on-time deliveries, too many small deliveries and not time-specific deliveries will cause in a high workload on the site and jeopardize the delivery- and the unloading plan. The CCC concept can be recognized as a compromised solution since the officials on the site cannot afford misses in the delivery plan because of its sensitivity and possible loss by failing the plan.

6.1.4 Lean Construction

According to Arbulu and Ballard (2004) in the theoretical part, a lean supply system in construction can be reached by dint of a strategy which include the implementation of the eight parts mentioned in subsection 4.2.2 The findings in the empirical part show that five of the eight parts of the strategy by Arbulu and Ballard (2004) is fulfilled by the case company Skanska today. Skanska is today using a Construction Consolidation Centre (CCC) in their

supply system at Citygate, Skanska is also using the strategy of pre-assembly the packages at least one day ahead their delivery to the construction site. Skanska will be using the pull method to deliver the assembled packages to the construction site. Skanska has not yet decided for how to call off the packages from the CCC. There are discussions about using a digital tool connected with the CCC to call the deliveries off but also to just have an Excel-file connected to call off the packages. The lack of a digital tool shows its presence when comparing Skanska's way of working and Arbulu and Ballard's (2004) strategy to achieve a lean supply system. According to Arbulu and Ballard (2004) the digital tool is a way to increase the reliability of the material flow into the construction site. The empirical study shows that Skanska experiences a lack of reliability in their supply system, they do not have control over the transports' arrival times. This issue is derived from loss of information among the long supply line as mentioned earlier. An interrelated system will increase the reliability of a retained information flow throughout the supply line and will increase the reliability of the supply system in its entirety. By implementing a digital tool which is interrelated through the supply chain, Skanska is deemed to have fulfil Arbulu and Ballard's (2004) strategy to achieve a lean supply system together with the way they already are working today at the project Citygate.

According to the theory of Swift Even Flow, activities as moving a delivery for the second time is a non-value-creating process and should be avoided to the most to maximize the value of a process. Storage of materials on site should then be avoided even if the dynamic of the construction site and space make this possible. As the Digital Block Manager mentioned, moving a delivered package twice is considered as a failure in the planning. This means that just-in-time deliveries can be seen as the optimal delivery method regardless the type of project or its condition, when creating the most value in a supply chain processes according to the theory of Swift Even Flow.

6.2 Work Environment Safety

The empirical study confirms the findings in section 4.6 that involvement of moving big vehicles and machines increases the safety risk on the construction site. These activities are mainly related to the unloading phase of logistics management. An issue raised in the empirical field is the involvement of different intermediates on the construction site such as sub-contractors that do not share the high safety demand with Skanska. The sub-contractors often consist of smaller companies that do not have equally experience of working in larger projects with higher safety risks as the larger companies. Many of the smaller companies also lack the financial conditions to prioritize safety in the level as the larger companies. As mentioned earlier, this problem is getting bigger since Skanska outsource the work more and more in their projects. A solution to this problem could be to educate the sub-contractor in order to aware them of the high risks on the construction site. On the other hand, this is a costly solution and it is not in Skanska's obligation to educate workers from other companies just because they are working on one of their projects. Here is an industry-organized solution needed in order to educate all the skilled works in the industry about the safety risks in order to have a safe work environment.

Another issue raised in the empirical study is the high stress level on the construction site that often comes with unplanned deliveries. When a delivery has arrived at the site, the contractor wants to unload the packages to the greatest extent possible, instead of having them coming back at another time which causes both delays and higher costs in the projects. Unloading of

unexpected deliveries entails much higher risks since the planning of these activities is crucial to lower the risk. When the officials have not had the opportunity to plan the execution of the unloading, the risk increases significantly for the happening of risky work activities which means that the risk of accidents increases. The latest fatal accidents have connection to the unloading phase on the construction site, such as the case presented in subsection 4.6.1. When studying these cases, it was concluded that by better preparation and planning, the fatal accidents could have been avoided. Whether these events occurred due to stress, poor planning or any other reason is not determined. However, the planning is strongly connected to decrease the safety risks. Unexpected deliveries make it impossible for a well-executed planning to take place. With more time spent on a work activity, the more thoughtful and better planning can be achieved which can eliminate the stress factor as well. However, the reason behind the high risks of the unloading phase is identified mainly as the difficulties to foresee the deliveries arrival which has been discussed earlier in this chapter. A better planning can reduce risky work activities from happening as well as decrease the stress level and provide more time to execute the unloading processes.

6.3 Digital Tools

This section analyses the similarities and differences between the background study and the empirical study regarding digital tools.

6.3.1 Visualization Ability of CLP

A problem found in the empirical study and the observation study is the difficulty with visualization of planning the Construction Logistics Plan (CLP). The CLP is usually planned in 2D and has historically been used to identify and plan the location of cranes, materials, transport roads etc. on the site. Today with space limitation of the construction sites and the big size of the projects, new tools are needed in order to better visualize the CLP and plan the logistics on the site. One potential solution to this problem is to take advantage of existing technology and Virtual Reality (VR). Another solution is the concept of Virtual Collaborative Design Environment which can be applied in CLP and logistics planning. Involvement of different stakeholders and their knowledge to collaborate and communicate regarding the logistics can result in a high-quality outcome. Having an integrated multi-touch table with VR-system can help to visualize the reality and get a better idea of how the site might look like in the future.

The drone-pictures can be used here as the basis and background in planning in order to provide a reality image of the site. The objective with this tool is to enable planning of logistics in 3D and easily check and control different scenarios during the planning time. For examples, trucks, cranes, construction elevator can be dragged and dropped on the touch screen in order to check a planned transport rout for a delivery. With the help of this tool it is possible to see in advance any deficiencies in the planning and to fix them before the operation takes place in reality.

Another solution is to take advantages of an existing software in the market, InfraWorks which provides the ability to quickly plan the site layout and the CLP in 3D. One of the advantages with this software is the ability to choose the detail-level of the model created in InfraWorks based on the users' skills and knowledge. Beside the visualized picture of the site layout that the 3D model can give, it is worthy to mention the ability to move around different vehicles

and components and measure in the software. This feature fulfills the need of trying different scenarios on the site layout during the planning phase, which was discovered in the empirical study. The disadvantages by the implementation of InfraWorks would be other digital tool to both learn and use within the different projects as well as an extended license expense.

6.3.2 QR-Code

During the empirical study, a need for a digital tool to register the delivery packages was discovered. This is reinforced by Mobasheri and Mohamed (2019) in the litterateur study in subsection 4.1.8. They found that officials on the construction sites experienced difficulties in the communication of where goods should be placed and stored on the construction site. The interviewees mentioned the ability of scanning a QR-code with a PDA in order to register the delivered packages on the site. Another feature that this function can be utilized for is the ability of having unloading instructions registered in the QR-code which can facilitate the unloading phase since all the instructions are available with the QR-code. Having the information such as the package's content will help the contractor and sub-contractors to see what is delivered in order to make sure that the material needed for a work task is in place and available on the site. The unloading instructions and other safety information available in the QR-code will facilitate the unloading phase and increase the safety on the construction site.

All this information mentioned above is already included in the BEAst Label model but is not used to a greater extend in practice. This is according to the findings partly due to the lack of requirement since it is only a recommended standard but also lack of required information in the suppliers' system is one of the reasons behind this issue. More guidelines and requirements are probably needed from both contractors such as Skanska and the entire industry in order to enable this function in the industry. This since it requires the suppliers to develop the information included in their supply systems to deliver the packages with BEAst Label. Then the QR-code on the BEAst Label can easily be scanned and the packages can be registered in a system with status update. Another benefit gained is related to the unloading moment since there will then be a consistent way to access the information and instruction for the unloading moment.

A problem raised in this matter is the matter of deliveries from abroad since BEAst is a Swedish standard and the members of this group are only Swedish companies and organization. This will then require the contractors to negotiate and make demands already from the procurement with the foreign suppliers in order to maintain a consistent and structured work routine on the construction site no matter if a delivery is supplied within or outside Sweden.

6.4 Obstacles and Barriers

This section analyses the similarities and differences between the background study and the empirical study regarding the obstacles and barriers found within the use and implementation of digital tools on the construction site.

6.4.1 Attitude and Culture

One of the underlying reasons identified as an obstacle to a more digitized industry is the people's attitude towards change which goes hand in hand with the existing culture on the construction site. This attitude is caused mainly because of the culture but also because of the

fact that change from the known to the unknown often causes people to resist the change as mentioned in subsection 4.5.2. Another aspect that makes this problem more complex is the wide range of knowledge of digital work sets and a wide range of age on the construction site which lead to mixed attitude and willingness towards change towards a more digital work set.

Theoretically, based on the discussion in subsection 4.5.2, this problematic attitude is partly because the people on the construction site who must use the new tools are often left outside of the decision-making process while deciding to implement new tools. As mentioned in subsection 4.5.2 this low degree of involvement in the decision-making process causes resistance towards the change. The cause of attitude along with the lack of interest will result in not taking advantages of the available digital tools on the site and since not everyone works with the digital tools, new problem arises. One of these problems is lack of information input and share in the digital tools and system since not everyone is using them in their work, namely inconsistent work sets arise which can lead into inefficiencies. Because of lack of information in the systems and digital tools, those who were in favor of change and the new digital work sets may now also become against the change. This was shown in one of the visited projects. The Construction Supervisor 1 and 2, that was very positive to digitalization decided to abandon the digital delivery calendar Centiro Universe partly because it was not used by everyone on the site and that lead to lack of shared information in the digital tools.

The problem in this case is that the personnel on the site experience the use of the digital tools as a task that takes more time and effort than the value it gives in return. The Construction Supervisor 1 and 2 had to first make an order of materials in IBX and later put in a delivery information manually in the delivery calendar Centiro Universe. In other words, they experience that there is no automatic transfer between the systems. This information in the Centiro Universe is then partly only available for themselves on the site and is neither shared with the delivery company nor the carrier. In this case, Centiro Universe becomes a digital version of an analog tool like the delivery whiteboard that is available on the site. All the information sharing takes place over phone calls and E-mails, in other words manually information handling is required. The possible changes in the delivery, if needed, has then to be putted in the Centiro Universe manually. This is both inefficient and creates a negative attitude among the personnel when they cannot clearly see the value that the digital tools can create. Beyond this, lack of information input by the sub-contractors decreases the value gained by using Centiro Universe since there will be deliveries booked by the sub-contractors that are not potted in the Centiro Universe. The sub-contractor's lack of cooperation in this tool is due to two major factors; no experience of using a digital delivery calendar and lack of seeing the value by using a digital delivery calendar. Here can the issue of having too many unrelated digital tools be seen. The Logistics Engineer argues that there is a connection between the information in the delivery calendar Centiro Universe and the supplier's systems. To be able to have this connection and utilize this benefit, a structured and correct order must be made in the purchase systems. This knowledge has clearly not reached the personnel in the different project at the construction sites since none of the interviewees at the construction sites shown any knowledge of this.

As discussed in subsection 4.5.2 the leadership becomes by high importance in order to get everyone involved and engaged while implementing a change. Involvement of all parties in the process creates a sense of participation that leads to increased acceptance of the change. This is one of the solutions to process the attitude. Another solution to this issue is to make people

understand the value and the possible benefits gained by implementing new digital tools. More positive outcome can be gained by having a clear vision and continuously communicate the vision with those that are affected by the change. Digital leaders that Skanska has introduced during the recent years, is a step for increasing the participation and communicating the vision.

Anyhow, it is also important to mention the importance of the company's organizational culture itself when it comes to change. In order to succeed with a change, it is necessary to have an organizational culture that is supportive and susceptible to change. But change is not easy and the difficulty of getting everyone on board always remains, especially in the large organization where many people are involved.

6.4.2 Existing Digital Tools Today

Many of the interviewees who work on the construction site experience that they are using too many digital tools in their daily work today. They specially pointed out that most of the digital tools used today are completely separated from each other. This means that they must manually put in the same information twice or more into different digital tools. Instead of having too many unrelated tools, the tools should be able to communicate with each other and share the information automatically without manual handling. This would benefit the organization in many ways, first as mentioned before, the loss of information would decrease, and the reliability of the information would increase. Second, as mentioned in the previous heading, the attitude towards these digital systems would be improved when the personnel do not have to repeat the same work of information input more than once in a system. Lastly, the experienced issue with too many different tools today would decrease due to that the systems would better be connected to each other and create a feeling of unity throughout the systems for the personnel.

Using Artificial Intelligence (AI) could be one solution to connect and make the systems communicate with each other. AI systems in the supply chain will help to reduce the error and provide in an improved supply system according to Vickranth et. al. (2019). By using AI and letting the system communicate with each other automatically, the error of the human factor will be reduced as well as it can result in reduced information loss and reduced waste of human resources which will result in increased productivity and quality. The objective with using AI is to develop digital platforms that enables all parties to process data and make it usable regardless of the data quality or format in order to enhance the supply chain process by increase the collaboration between man and the digital systems. One of the most common problem that occur when information and data transfer between different system is lack of interoperability, which will be discussed in the heading below.

6.4.2.1 Designated Time to Learn Digital Tools

Another existing problem identified in the empirical study is the lack of designated time to learn to work with the digital tools. The interviewees claim that there are often new digital tools introduced to them in new projects which in turn causes problem. When new tools are introduced for the personnel in projects, time need to be set of to learn the new digital tools. Every tool has to have a start-up period before the personnel can make use of the digital tool in an efficient way and to fulfill the purpose of the digital tool. Implementing or introducing new digital tools without enough time being set off for the personnel to learn and without developing an understanding for the digital tools will rather cause in negative attitude towards

digitalization on the construction site than create a value. Skanska's work with Digital Development Managers and digital leaders is one way for Skanska to deal with this problem. By transferring knowledge about the digital tools further down the organization into each of the project's necessary competences about the digital tool will exist where they are needed, in the production. Despite this, time need to be set of to learn and implement the digital tools for the personnel in the projects to enable an efficient use of them in each project. According to Kotter's model, presented in the theoretical part, the organization will need to follow eight specific steps to implement a change successfully whereas step number five is about to ensure the right ground conditions for the change. In this case, time to learn and implement the new digital tools is one crucial condition for the implementation of a new more digital way of working.

One factor that largely affect the time spent to learn a new digital tool is the user-friendliness of the digital tool. The interviewees stated the lack of user-friendliness in the digital tools as one of the main challenges today. The wide range of both age and knowledge of digital tools puts a great demand on the user-friendliness of the digital tools meant to be used on the construction site. Although the interviewees mention that the user-friendliness has gotten better with the years there is still a lot of improvement needed in the future to enable a more successful digital logistics management work. The user-friendliness of a digital tool is crucial in many aspects. Firstly, the more user-friendly a digital tool is less time will be needed to learn and implement the digital tool in the organization and on the construction site. Secondly, if the digital tool is easy to use and the value creating by using the digital tool is easy to identify the attitude among the personnel will become better towards using the digital tool. Lastly, if the digital tool is user-friendly it will streamline the logistics management work with less issues and a better flow in the daily work. As mentioned in subsection 4.5.1 there is scientific proof of the benefits that a user-friendly digital tool can provide. According to Blake (2010), a way to create good user-friendliness is to limit the number of functions that can be performed simultaneously. By diversifying functions and futures into large categories instead of having all the features available at once can be one possible solution for this. Anyhow, this method can be considered more difficult than directly getting to the desired function, but it reduces the burden on the brain when less thought is required according to Blake (2010).

6.4.2.2 Change of Software

Another issue discovered during the observation study was that Skanska can be forced to change the software supplier of the digital tools when the license costs increase. To change the supplier of the digital tools to another one with similar functions due to economic incentives causes problem such as another new start-up and learning period of the digital tools. When Skanska invests time to learn and implement a new digital tool from a certain software supplier a dependency from Skanska to the supplier is created. This in turn leads to that the supplier can take advantage of the dependency and increase the price of their license for their products that Skanska is using. Then Skanska will be forced to either change supplier or pay for a higher license cost. This dilemma can be hard to find a solution to, to ensure a reasonable license price, a two-way dependency need to be created. This means that no party is more dependent on the other party. The two-way dependency can be reached through free trade which means that Skanska always will be choosing the supplier with the lowest licenses cost for a similar product which is like the case today. It can also be reached by a longer partnership between

Skanska and the supplier, a partnership like what Skanska and Autodesk is discussing to develop today.

6.4.2.3 Digital Purchase Tools

Today, many of the personnel on the site choose to place an order over phone and E-mail instead of the available purchase system such as Fusion, IBX or Spik. As presented earlier in subsection 5.5.2, a proper and structured order in the purchase systems can be copied to the delivery calendar Centiro Universe and thereby if the transport is booked via DHL, an automatically status update will be available in the delivery calendar. This means that the technology and the tools are already in some extent available and existing on the site but what is lacking is the crucial orders to be placed via purchase systems and not over phone calls or E-mails. One underlying reason is the complexity they encounter to place larger orders. This creates an inconsistency which makes those deliveries that are registered and have a status update lose some of their significance and effect as there are other deliveries that are not registered in the same way. This will in turn create inefficiencies as there is different information about the deliveries.

6.4.3 Interoperability

Lack of interoperability has been identified both in the empirical field and the literature study as an obstacle to having a more digitized industry. This is mainly because of different file-formats used in different systems which in turn requires manual conversion in order to bring them together in the same software. As mentioned in subsection 4.5.3 interoperability in the construction industry increases the productivity on the construction site meanwhile poor interoperability will create inefficiency and unproductiveness. This lack of interoperability has in turn led to an attitude towards digitalization since it requires manual handling which is a time-taking process. A possible solution to this mentioned obstacle is to have more industry-standardized file formats but also a higher ability in the different software to accept different raw file formats.

This lack of interoperability affects directly the creating of Construction Logistics Plan (CLP) in 3D since the drone-files have to be converted manually several times before they can be imported to the desired software such as NavisWorks or InfraWorks. A desired function is to have the software to accept the original raw file-format of the drone-file such as las. This requires a development of the existing software. This solution requires a dialogue between the actors in the industry with the software development companies such as Autodesk in order to coordinate the needs and opportunities. This open dialogue will in turn set the software development in the right direction which can fulfill the existing needs and interoperability issues today. Another possible solution as mentioned in the heading above is to create an AI program that can automatically convert the drone-files to the desired format that the software accepts i.e. fbx. This solution will in turn decrease the manually handling effort which can be seen as an increased user-friendliness that will facilitate the process and also create a positive attitude towards digitalization. It is worthy to mention that fbx is accepted by Autodesk's software since it has lower size compared to las and the original Mesh-files.

7 Discussion

The following chapter starts with a discussion of the result and the analysis of the study and continues with a discussion from an ethic and sustainability perspective. Later in this chapter, the validity of the study is discussed and suggestion for future studies are proposed.

7.1 Result Discussion

In the previous chapter, different problems with its underlying issues has been analyzed and several different and mutual solutions has been suggested to the identified problems. The authors have chosen to compile the analysis below and discuss them coherent to be able to remove any ambiguities. But, also to compile the various proposals that are repetitive in some cases in order to simplify the reading and provide the readers a clear picture with increased understanding.

Co-loading and delivery have been suggested as a solution in order to reduce the amount of small deliveries but there is a long way to get there. Planning and collaboration is highly crucial in order to utilize the concept of Co-loading and delivery. Since the planning of material consumption and different deliveries will take place already in the procurement phase, a long-term and comprehensive understanding by all parties is needed. This also means a change in the current way of working and the culture since the planning will take place on a completely different level. It is by high importance here to take advantage of the knowledge and experience among the people who has worked in the production. This, in order to estimate more accurate since those people are familiar with the material consumption and can help to manage the logistics already in the procurement phase. This solution can solve the problem of high small deliveries and increase the opportunity to monitoring and status-updating of deliveries. The reduced amount of deliveries will facilitate monitoring of the deliveries since there will be fewer deliveries to handle on the site. The administration and the handling time will then reduce, which means that time and cost can be saved.

A future study to measure a tangible value of Co-loading and delivery is recommended. It will in turn create a clear understanding and help to convince the management and other people involved in the projects of Co-loading and delivery's benefits and values. On the other hand, clear and concrete values and numbers are difficult to measure since the projects are complex and many factors are interrelated and depend on each other. It is difficult to isolate only one parameter and see what value it gives instead of the traditional way of working. It can also be seen as a wrong focus, to put resources on measuring such a value. This is similar to the development of BIM and clash checking since the management wants to see how this new concepts and work-sets can save time and money.

The concept of Construction Consolidation Center (CCC) has also been suggested as a solution to reduce the high number of deliveries, and also in order to avoid the issues related to the arriving time of a delivery. This solution can be considered as a workaround which do not create any value by itself, it is just a solution that relocates the issues of deliveries to another place than the construction site. But since there is no time and space on the construction site to deal with these issues, this solution becomes very interesting due to the circumstances. The problem with high number of deliveries or uncertainties regarding the arrival time are then addressed to the CCC and the personnel on the site will be able to avoid them in their daily

work. Another advantage by this solution is the process control that can be gained, the packages can be checked at the CCC, and detected errors can be fixed at the CCC before their shipment to the site.

One concern that has been discovered during the study which is very important to get the implemented digital tools working at their best, is to get everyone involved in the project to use those tools. It is by high importance to understand that the tools cannot be better than the information they contain, and the information must to some extent be entered by those working on the site. Therefore it is crucial to make everyone, contractor and sub-contractors, to work in those tools on the site in order to have consistent work sets. By not having everyone working in the tools, information will get lost and the tools will become inefficient since not everything is available in the tools. This is what has been discovered at one of the visited projects. It is important to mention that what actually is needed is a change in the way of working and the culture. Instead of interpreting the analogue and traditional ways of working into digital platforms, the work-sets need to be developed and changed as well. This, in order to for example see the digital delivery calendar Centiro Universe as a new digital tool that means new routines and work-sets instead of seeing it as a digital version of a whiteboard.

User-friendliness is a factor that must always take into consideration in the development of new digital tools for the AEC industry, specially the tools used on the construction site. One way to attract people to work with digital tools is the ability to prove that the tools are easy to use and that they can save time by working with digital tools instead of working in the traditional ways. A user-friendly digital tool will be easier to use, easier to understand which can encourage the personnel on site to use these digital tools. As mentioned earlier, an increase in the use of digital tools means that the digital tools can live up to their best potential and thus efficiency can be utilized. User-friendliness will also shorten the learning time which is also very important in order to use the digital tools on the construction site. The digital tools should be adjustable to its users by having different level of detail and advance.

When it comes to digital development and digitalization, Autodesk is much further in the digitalization and their tools are further in development than Skanska and the construction industry today. Autodesk's tools require a lot of expertise and knowledge, but also a lot of structure and a high detail level in the work. This means that new routines and work-sets have to be created, work-sets which align with these tools and not just an interpretation of the traditional work-sets. Since, the digital tools are not used effectively in a larger extend, many of the functions today are too difficult to use and many of the personnel on the site do not know how to utilize them. Advanced Work Packaging, for examples, requires a high level of detail and structure both in the model and in the work-sets, e.g. status updating of a specific component in the model. Models today are not built in this way due to different reason.

There are a lot of standards existing today and more are of course needed but what is really important is to use those standards in the industry. The BEAst Label standard is one of them, which contains all the information that interviewees on the construction site would like to have on a package label. But this standard is not used due to different reasons, one of them is lack in the suppliers' systems. It is costly for the suppliers to invest in new systems and implement those standards, and it becomes even more difficult to get them to invest in systems and tools if there is no need or requirement from their client which are in this case the main contractors and the sub-contractors. There is a need from the contractors to put demands on the suppliers

to utilize the standards. It is worthy to mention that this standard has been developed in BEAst group, where both the contractors such as Skanska and suppliers such as Derome and Ahlsell are members.

The strategy of Arbulu and Ballard (2004) to develop a more efficient supply system has been used in the study to develop a more efficient logistics management. This strategy is just one of many methods to make logistics management more efficient. There are more theories, concepts and strategies which could have been used instead but the choice ended up on this due to applicability to the study. It supports the idea of Construction Consolidation Center (CCC) and states the need for a digital tool.

Some of the suggested solutions to the research question means implementation of new digital tools such as InfraWorks, Assemble etc. The implementation of new digital tools requires designated learning time for the personnel which has already been discovered as an existing problem. This arise a paradox which has to be solved correctly. Lack of designated learning time is already an existing problem today which need to be considered highly while implementing new digital tools. It is by high importance that the personnel on the site have the knowledge to work with the tools before they enter the project in the production phase. This is crucial since they will have full production and not much time to learn the new tools. This can also create a positive attitude to using the digital tools as they already are familiar and feel comfortable with the tools.

Another problem raised with the suggested solutions is the paradox of implementing new digital tools meanwhile one of the problems identified today in the empirical study is the high number of digital tools. One reason behind this as mentioned earlier, is the lack of system interrelation which creates negative attitude and obstruct the digitalization. In this case, the system interrelation is very crucial in order to solve this paradox. There is a need for higher system communication between the tools in order to avoid manual information handling. Having interrelated systems that can exchange and transfer data automatically will decrease the feeling of too many different digital tools. For example, the interrelation between the delivery calendar used by Skanska and the supplier and carrier's delivery calendar when a delivery is booked via DHL and the order has been placed through the digital purchasing systems. Any information or updates from the supplier or the carrier can directly be reported to the delivery calendar instead of updates and information exchange via E-mail or phone calls. The information transfer over phone calls and E-mail requires the personnel on the site to manually update the delivery information in the delivery calendar beside that it might interrupt them in their work which creates inefficiencies and unproductivity. This system interrelation instead will create the feeling of having one joint system instead of different separate tools since the manual workload has been decreased. This interrelation will in turn help the personnel to see the benefits and values of using the digital delivery calendar instead of traditional delivery calendar on a whiteboard.

7.2 Ethics and Sustainability

Every human being should feel secure when going to their work. Knowing that they will return home safe and healthy should be a matter of course, this includes both physical and mental health. Stress on the construction site can lead to both fatal accidents and mental illness. As presented in the Empirical chapter a better planning of work tasks leads to less stress. Better structure and control over when deliveries arrive will reduce stress as well. Although not stress has been proven as a cause of the three accidents with fatal outcome the last three years at Skanska, there is most likely a connected to it. In all cases, the accident has happened in most likely stressful situations when the planning has been poor and, in some cases, non-existent. By working more digitally, time could be saved through utilize the possibilities by automatic information transferring and easier visualizations tools. This in turn, can certainly lead towards better conditions that enable better planning and greater control over the various work tasks at the construction site. Spending resources to further develop a more efficient way of working with logistics management can save lives in the future. Therefore, it should be a matter of course for all construction companies to work towards this goal, so that all employees can go to work and feel safe.

All the materials and the goods are transported to the construction site by trucks both from the inside the country and abroad. The high number of transports causes a high carbon dioxide emission which can be reduced by different solutions and actions. Co-loading and delivery and better material consumption planning can result in a reduced amount of transports to the site which has a direct impact on carbon dioxide emission. Fewer transports can lead to better transport flows which will results in a more sustainable industry. Another solution that can be discussed from a sustainability perspective is the concept of Construction Consolidation Centre (CCC). There will be a transport from the CCC to the site beyond the material and goods transports to the CCC. But it does not necessarily mean an extra delivery in all cases, large quantities of material can be delivered to CCC in one transport which can be further distributed to the site when it is needed. This is again about planning and optimizing deliveries to have an even material flow to the site while keeping carbon dioxide emission in mind.

7.3 Future Research

There is a need for a future study that examines the possibility of measuring the value created using digital tools at projects and in the organization. The study has shown that there is no tangible value measured yet that shows the value gained using digital tools in logistics management. A possible measurability of this would have enhanced for a faster change and development in the use of digital tools. Although, such measuring is considered to be very difficult, therefore future study should be based on finding methods and models which enables this measurement in the future.

8 Conclusion

Based on the conducted literature studies and in agreement with all the interviewees, it is considered that there is great development potential and opportunities in logistics management on site. The study shows that logistics management can be improved with the help of digital tools and work-sets. Digital tools and digital work-sets can facilitate the planning and operating of construction logistics management. The analysis shows that solutions as Construction Consolidation Centre (CCC) and Co-loading and delivery will result in fewer deliveries to the construction site which can enhance status updating and process control of the supply chain by the help of digital tools.

Based on the analysis and in agreement with all the interviews, the safety on the construction site will increase by the help of digital tools. The safety will partly increase since more process control of the supply chain is created. The delivery time and delivery information such as information regarding the unloading will be available digitally which will enhance the unloading process. On the other hand, digital tools such as InfraWorks can help to plan the Construction Logistics Plan (CLP) in 3D to increase the efficiency and anticipate the risks connected to the logistics management such as unloading processes.

The analysis shows that one of the main reasons for the prevailing situation in logistics management today is the cultural aspect and the attitude towards digitalization. Lack of interest from people on site has resulted in the existing digital tools not being fully utilized and, in some cases, even stopped being used completely. There is a need for changes in the culture among the people on the construction site in order to succeed with the digitalization. The analysis shows also a need for creation of more structured and suitable work-sets to work more digitized instead of interpretation of traditional and analogue work-sets.

However, in order to succeed with the implementation of new digital tools, it is extremely important to change the culture and attitude towards digitalization in the industry, but especially among the people on the construction site. One possible solution is to make the tools user-friendly and easy to use in order to get everybody involved in the project to work in those tools. It is also by high importance to be able to clearly demonstrate the benefits of its use in daily work. Furthermore, it is important to think about giving people time to learn those tools before they are put into projects in order to be able to use those tools in their daily work. There is also a need for more central guidelines and demands in order to get a unity in the processes and work-sets for all the projects in the organization.

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9.2 Pictures and Figures

Figure 1. Skanska. (2019). *Uppkopplad byggplats – Skanska*. Retrieved from https://smartbuilt.se/library/4847/6-lotta-wibeck_20190521.pdf

Figure 2. Mobasheri, F., & Mohamed, N. (2019). *Improved logistics using BIM-design* (Bachelor's thesis, Royal Institute of Technology in Stockholm, Architecture and Civil Engineering). Retrieved from <http://kth.diva-portal.org/smash/get/diva2:1354314/FULLTEXT01.pdf>

Figure 3. McKinsey. (2015). *Imagining construction's digital future*. Retrieved from <https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/imagining-constructions-digital-future#>

Figure 4. Roupé, M., Johansson, M., Maftai, L., Lundstedt, R., & Viklund-Tallgren, M. (2019). Seamless Integration of Multi-touch Table and Immersive VR for Collaborative Design. In *Advances in Informatics and Computing in Civil and Construction Engineering* (pp. 263-270). Springer, Cham.

Figure 5. Roupé, M., Johansson, M., Maftai, L., Lundstedt, R., & Viklund-Tallgren, M. (2019). Seamless Integration of Multi-touch Table and Immersive VR for Collaborative Design. In *Advances in Informatics and Computing in Civil and Construction Engineering* (pp. 263-270). Springer, Cham.

Figure 6. BEAst. (n.d.). *Förpackningsstruktur*. [Online Image]. Retrieved from <http://www.beast.se/standarder/beast-label/forpackningsstruktur/>

Figure 7. Mullin, L. (2016). *Infracore Model Builder to construction site design in minutes*. Retrieved from <https://www.youtube.com/watch?v=RCGTlcYi9cA>

Figure 8. Autodesk. (2018). *Advanced Work Packaging: Aligning the Autodesk project delivery platform*. Unpublished manuscript.