Tampereen yliopisto

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HOW DIGITALIZATION CAN ENHANCE THE EFFICIENCY OF THE PROJECT SUPPLY CHAIN

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ABSTRACT

Tuomas Rahkola: How digitalization can enhance the efficiency of the project supply chain
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Digitalization has been identified as a major trend affecting the society and the business both in short and long term. Even though there are multiple studies about the benefits of digitalization for supply chains, the main focus has been on supply chains with relatively high product quantities and predictable demand for products. However, in a project supply chain the quantity of products is relatively low (unique products) and demand is unpredictable. Therefore, this study examined how digitalization can enhance seamless material flows and sufficient information sharing in a project supply chain which ultimately leads to enhanced efficiency of the whole project supply chain. Furthermore, this study identified main obstacles for seamless information flow and sufficient information sharing.

In the literature review, the supply chain management theory was covered and it suitability to project context was considered to identify the characteristics of a project supply chain, and what are the main obstacles for sufficient information sharing and seamless material flows in a project supply chain. Furthermore, the impacts of digitalization for supply chains were examined and suitability of digital technologies and applications to improve information and materials flows in a project supply chain was considered. The empirical study mainly consists of semi-constructed interviews with the case company's key personnel involved in the project business and three subcontractors from the Baltics were also interviewed. The interviews revealed main issues related to material flows and information sharing in the case company`s recent projects. Additional primary data was gathered from the case company's systems and from informal discussion with the employees.

In this research, lack of material flow coordination between supply chain members, insufficient procurement planning and manual material flow processes and lack of material traceability and material identification were identified as main obstacles for seamless material flows in a project supply chain. The main problems for sufficient information sharing in a project supply chain were lack of trust between supply chain members, different information systems and lack of interoperability, poor supply chain visibility, too many emails and manual data collection. Based on the literature research and the empirical study, main digital technologies to enable prompt information sharing and increased efficiency in the project supply chains are: robotic process automation (RPA), Cloud computing (SaaS), Quick Response (QR) codes and radio-frequency identification (FRID) technology. One of the main benefit of digitalization for a supply chain is increased supply chain visibility. Therefore, one possible future research topic could be how digitalization can enhance the real-time visibility of outsourced manufacturing and what kind digital technologies support real-time remote manufacturing progress monitoring.

Keywords: digitalization, project, supply chain, material flow, information sharing.

TIIVISTELMÄ

Tuomas Rahkola: Kuinka digitalisaatio voi parantaa projektitoimitusketjun tehokkuutta
Diplomityö
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Digitalisaatio on megatrendi, joka vaikuttaa yhteiskuntaan ja liiketoimintaan lyhyellä ja pitkällä aikavälillä. Vaikka digitalisaation hyödyistä toimitusketjuille on tehty useita tutkimuksia, niiden pääpaino on ollut toimitusketjuissa, joissa tuotevolyymi on suuri ja kysyntä ennakoitavissa. Projekteissa sen sijaan tuotevolyymi on suhteellisen pieni (ainutlaatuiset tuotteet) ja kysyntä vaikeasti ennustettavaa. Tässä tutkimuksessa tarkasteltiin, kuinka digitalisaatio voi tehostaa saumatonta materiaalivirtaa ja riittävää tiedon jakamista projektitoimitusketjussa, mikä lopulta johtaa tehokkuuden kasvuun koko projektitoimitusketjussa. Lisäksi tutkimuksessa tunnistettiin tärkeimmät esteet saumattomalle materiaalivirralle ja riittävälle tiedon jakamiselle.

Kirjallisuuskatsauksessa käsiteltiin toimitusketjun hallinnan teoriaa ja tarkasteltiin sen soveltuvuutta projektikontekstiin, minkä pohjalta tunnistettiin projektitoimitusketjun ominaispiirteet ja mitkä ovat tärkeimmät esteet riittävälle tiedon jakamiselle ja saumattomille materiaalivirroille projektin toimitusketjussa. Lisäksi tarkasteltiin digitalisaation vaikutuksia toimitusketjuille ja mitkä digitaaliset teknologiat ja sovellukset soveltuvat parantamaan tiedon ja materiaalin kulkua projektitoimitusketjussa. Empiirinen tutkimus koostui pääosin projektiliiketoimintaan osallistuvien avainhenkilöiden puolistrukturoiduista haastatteluista. Lisäksi haastateltiin myös kolmea alihankkijaa Baltiasta. Haastattelut avasivat keskeisiä ongelmia materiaalivirtoihin ja informaation jakamiseen liittyen tapausyrityksen sen hetkisissä projekteissa. Lisätietoa hankittiin tapausyhtiön järjestelmistä ja epävirallisista keskusteluista työntekijöiden kanssa.

Tässä tutkimuksessa keskeisiä esteitä saumattomalle tiedonkululle projektin toimitusketjussa olivat toimitusketjun jäsenten välisen materiaalivirtojen koordinoinnin puute, riittämätön hankintasuunnittelu ja manuaaliset materiaalivirtaprosessit sekä puutteellinen materiaalin jäljitettävyys ja tunnistaminen. Suurimpia ongelmia riittävälle tiedon jakamiselle tapausyrityksen toimitusketjussa olivat toimitusketjun jäsenten välinen luottamuksen puute, erilaiset tietojärjestelmät ja järjestelmien yhteensopimattomuus, toimitusketjun huono näkyvyys ja liian monet sähköpostiviestit sekä manuaalinen tiedonkeruu. Tutkimuskirjallisuuden ja empiirisen tutkimuksen perusteella tärkeimmät digitaaliset teknologiat, jotka mahdollistavat nopeaa tiedonjakoa ja tehokkuuden kasvua projektitoimitusketjuissa ovat robottiprosessiautomaatio (RPA), pilvipalvelu (SaaS), QR-koodit ja FRID-teknologia. Yksi digitalisaation suurimpia hyötyjä toimitusketjussa on läpinäkyvyyden parantuminen. Siten kaivattaisiin lisää tutkimusta siitä, miten digitalisaatio voisi parantaa ulkoistetun valmistuksen reaaliaikaista näkyvyyttä ja millaiset digitaaliset teknologiat tukevat reaaliaikaista valmistuksen edistymisen seurantaa.

Avainsanat: digitalisaatio, projekti, toimitusketju, materiaalivirta, tiedon jakaminen.

PREFACE

This master’s thesis was written during the year 2021 in collaboration with Nepean Conveyors Oy and Industrial Engineering and Management unit at Tampere University.

I would like to specially thank to my supervisor Mikko Järvinen as well as Jukka Korhonen from Nepean Conveyors Oy to make all the interviews possible.

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Lahti, 02.11.2021

Tuomas Rahkola

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1. INTRODUCTION

1.1 Background

Digitalization has been identified as a major trend affecting the society and the business both in short and long term (Parvinen et al. 2017). There is hardly any aspect of life which haven’t impacted by the digitalization and supply chains aren’t exception. The COVID-19 pandemic has negatively impacted organizations all around the world and challenge supply chains to be more resilient against disruptions and uncertainties. In order to withstand similar crisis in the future, organizations are forced to adapt their business models and acquire new competencies to grow their resilience. The COVID-19 pandemic has accelerated the digital transformation in organizations and there is growing awareness of the benefits of supply chain digitalization. (Gapgemini Research Institute 2020)

Many project-based industries such as the construction industry are very conservative when it comes to adaptation of new digital technologies in their supply chains. However, at the same time these very same industries suffer from poor supply chain visibility which results delays in the project and affecting the performance of whole supply chain. (Behera et al. 2015; Liu & Chua 2016) Even though there are multiple academic publications about the supply chain digitalization, these publications many times focused on process-based industries where demand is relatively predictable and volume is high. However, in many project supply chains the quantity of products are low and demand is unpredictable Therefore, there is need for further study how digitalization can enhance the efficiency of the project supply chain.

Material flows have huge impact on project supply chain’s performance since material costs make up significant percentage of total goods capital project costs and incorrect materials and material delays make up to 50 percent of project delays and cost overruns. Furthermore, project supply chains involve a lot of shared information among the supply chain members since products are complex and customer requirements affect greatly on the final products. Information sharing and communication can be also major cost driver in the project supply chain if majority of information is travelling through an unorganized and inefficient fashion. (Liu & Chua 2016; Shash & AbuAljana 2021) Therefore, in this masters' thesis the focus is on the materials and information flows and how digitalization can enable seamless flow of materials and information in the project supply chain.

1.2 Research question and limitations

The case company in this research is Nepean Conveyors Oy who is specialized in bulk material handling projects. The case company is dealing with complex projects with shortening lead time and constant scope and design changes. The material costs are significant percentage of the total project costs and therefore, they play big role how competitive project the case company can deliver compared to its competitors. The most of the activities related to actual project execution are outsourced such as manufacturing and installation of the equipment. Since the case company has suffered from low margin projects and existing local and global competition has put a lot of pressure to lower project margins even more, there are clear need for more efficient supply chain.

Digitalization has been a "buzzword" for decades know but in the case company most of the daily activities and based on emails and spreadsheets or even paper sheets. Büyüközkan and Göçer (2018) state that digitalization "enables the evolution of the next generation of supply chains offering both flexibility and efficiency." This thesis will try to answer the following research question:

How digitalization can enhance the efficiency of the project supply chain

This question will be answered by answering the following sub-questions:

What are main obstacles for sufficient information sharing and seamless material flows in the project supply chain

What digital technologies and applications enable sufficient information sharing and seamless material flow in the project supply chain

The project supply chain in this context is limited to material and information flow between the case company, subcontractors responsible for steel structure manufacturing and the construction site where equipment are installed and commissioned.

1.3 Objectives

The objective of the master's thesis is to identify main obstacles for sufficient information sharing and seamless material flows in the project supply chain and how digitalization can enhance the efficiency of supply chains in project environment. Furthermore, suitable digital technologies and applications are search from the literature to enhance the project supply chain's material flows and information sharing.

1.4 Structure of thesis

This master's thesis is divided in the seven main chapters which are *introduction, literature review, case company introduction, case study, results and analyzing results and discussion and conclusion*. In the literature review first sub-chapter 2.1 is about supply chains and supply chain management in general and what concepts are related to these themes. In sub-chapter 2.2 supply chain concepts are considered in the project context to define a project supply chain and how material and information flows affected the efficiency of the project supply chain. Finally in sub- chapter 2.3 the impacts of digitalization to supply chain are analyzed and what digital technologies and application can enhance the seamless flow of information and materials in a project supply chain. Chapter 3 is about the introduction of the case company and chapter 4 explains the chosen methodology for the research. Chapter 5 presents the result of the empirical research and in chapter 6 results are analyzed. Final chapter 7 is discussion and conclusion where the finding of the master's thesis are summarized and this study is linked to academic research and topics. Also possible future research topics are presented in this chapter.

2. LITERATURE REVIEW

2.1 Supply Chain Management

2.1.1 Definition of supply chain and supply chain management

A supply chain can be defined as the network of organizations that are directly involved through the upstream and the downstream linkages, to produce the value to the ultimate customer in the form of products and services (Mentzer at al. 2001). Organizations linked through the upstream can be considered as suppliers who are supplying raw materials, components, or services to the focal organization. Organizations in the downstream on the other hand, are involved in the distribution of the final products or services. (Mentzer et al. 2001) Furthermore, a supply chain consisting of all the operations, activities and the processes which are required to turn the raw materials into final products and delivering them to the ultimate customers (Hugos, 2011 p.16-19). Figure 1 presents how the upstream and the downstream are divided in the supply chain.

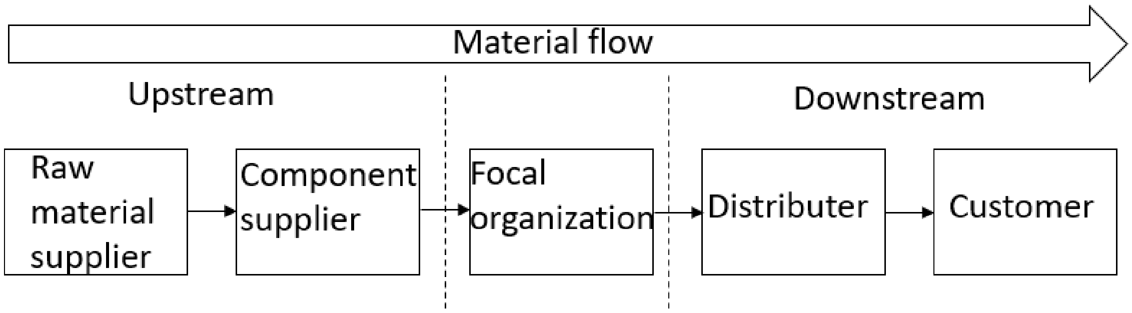

***Figure 1**. Supply chain.*

The concept which is directly linked to supply chain is *Supply Chain Management* (SCM). SCM is well established concept both in academia and business practice. The term "*supply chain management*" first appeared in the literature in the 1980s and came into common use in the 1990s . (Cooper at al. 1997; Hugos 2018, p. 3) Even though the concept of supply chain management is well established, multiple definitions can be found in the literature. Due to the lack of all-encompassing definition of supply chain management, it is necessary to define supply chain management relevant to this thesis. Based on the literature review the following definitions of supply chain management have been found.

"Supply chain management is the integration of business processes from end user through original suppliers that provides products, services and information that add value for the customer (The International Center for Competitive Excellence 1994, cited in Cooper et al. 1997)."

Supply chain management is "the systemic, strategic coordination of the traditional business functions and the tactics across these business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole (Mentzer et al. 2001)."

"Supply chain management is the management of relationships in the network of organizations, from end customers through original suppliers, using key cross-functional business processes to create value for customers and other stakeholders (Lambert 2014, p.2)."

"Supply chain management is the coordination of production, inventory, location, and transportation among the participants in a supply chain to achieve the best mix of responsiveness and efficiency for the market being served (Hugos 2018, p.4)."

La Londe (1997) defines SCM as the process of managing relationships, information and material flows across the organizational boundaries to deliver services and products which provide enhanced customer value through synchronized flow of materials and associated information throughout the supply chain. Based on the definitions presented above, SCM is systematic approach to integrate business processes across organizational boundaries to efficiently coordinate material and information flows in the supply chain. Lambert (2014, p.2-7) states that management of relationships is the cornerstone for successful integration of cross-functional business processes across the supply chain. How successfully business processes can be integrated across enterprise boundaries depends greatly on the type of relationships nurtured in the supply chain. Before any integration of business processes can be made, it is important to identify key business processes in SCM context.

2.1.2 Supply chain management processes

Business processes can be defined as a structured set of activities to produce specified output of value to the customer (Cooper et al. 1997; Lambert 2014, p.8) How these activities are structured, is the key element of creating superior performance. Traditionally business processes have been used to integrate different business functions within a company. Since companies don't compete entirely as autonomous entities, but rather within supply chains, the success of the business depends on how well the business processes have been linked and managed across the companies in the supply chains. (Lambert 2014, p.2-8) Structured set of activities which are integrating and managing key business processes across companies in supply chains can be defined as Supply Chain Management Processes (Lambert 2014, p.10) The Global Supply Chain Forum has identified the following supply chain management processes (Lambert 2014, p.10) :

- Customer Relationship Management
- Supplier Relationship Management
- Customer Service Management
- Demand Management
- Order Fulfilment
- Manufacturing Flow Management
- Product Development and Commercialization
- Returns Management

Customer Relationship Management is a set of structured activities to develop and maintain relationships with customers. The purpose of Customer Relationship Management (CRM) is to segment the customers based on how profitable they are and developing relationship with the key customers in a such way which enables to eliminate non-value adding activities. Furthermore, CMR normally includes IT-tools to gather information about the customers and analyzing it in order to provide customized products and services which are increasing customer satisfaction and loyalty. Lambert (Lambert 2008, p.25) states that there are strong correlation between profit growth and customer satisfaction and customer loyalty.

Supplier Relationship Management is a set of structured activities to foster and manage relationships with key suppliers. Suppliers are segmented based on the value they provide for the focal company. Building a strong cross-functional relationship with key suppliers with mutual benefits and maintaining more traditional buyer and salesperson relationships with other suppliers is the essence of *Supplier Relationship Management*. (Lambert & Schwieterman 2012)

Order Fulfillment includes activities to design a logistics network to fill customer orders and permit the focal firm to meet customer requests cost efficiently (Croxton 2003). The seamless order fulfilment process requires cross-functional integration, but it can affect the financial performance. For example optimized order-to-cash cycle decrease the inventory level which frees up the capital engages to the inventories. (Croxton 2003). *Customer Service Management* represents a single point of contact for the customer and provides a source of up-to-date customer information, such as order status and shipping dates. (Bolumole et al. 2003). Well-managed customer service management process should pro-actively identify and solve problems before they affect customers. Customer service management team interfaced with other business process teams to ensure that promises made to the customers are kept.

Demand Management is a process of balancing and synchronizing customer requirements with supply chain capacity and capabilities (Croxton et al. 2002). Furthermore, it enables a company to be more proactive to anticipate demand and more flexible to anticipated demand. The main components of demand management are to find ways to improve operational flexibility and eliminate management practices that increase the variability. (Croxton et al. 2002)

Manufacturing Flow Management is a supply chain management process that includes all the activities to establish the right level of manufacturing flexibility in the supply chain and manage the flow of products into, through and out of the plants (Lambert 2014, p.12). Determine the adequate level of manufacturing flexibility requires cross-functional planning and execution of manufacturing flow management. All the business functional involved, should work closely with production to ensure efficient material flow into and out of the production. Therefore, manufacturing flow management is more than just production and affects the efficiency of the whole supply chain. (Lambert 2014, p.12).

Product Development and Commercialization is the supply chain management process providing the structure for developing and bringing new products to the market jointly with other supply chain members (Roger et al. 2004). Effective implementation of product development and commercialization process not only enables coordination of efficient flow of new products thought the supply chain, but assists other supply chain members in product commercialization activities (Lambert 2014, p.12). *Returns Management* is a supply chain management process that manage reverse logistics in the supply chain. The reverse flow of products not only should be efficient, but the management should try to find ways to reduce the unwanted returns and control reusable assets such as containers.(Lambert 2014, p.12-13)

SMC doesn't only strive to integration of business processes, but encompasses four facets: relational integration, process integration, information integration and cross-functional teams (Paulraj et al. 2006). In other words, SCM practices lead supply chain integration. According to Vijayasarathy (2010) supply chain integration refers to " the adoption and use of collaborative and coordinating structures, processes, technologies and practices among supply chain partners for building and maintaining a seamless conduit for the precise and timely flow of information, materials and finished goods." Tan

(2001) argued that a well-integrated supply chain involved coordination of material and information flow across the whole supply chain.

2.1.3 Information and material flow in supply chain

Three main flows in the supply chain are: material flow, information flow and finance flow. The material flow is mainly from upstream to downstream of the supply chain and the finance flow is mainly on the opposite way. The information flow on the other hand, is bidirectional and the amount of information in the supply chain is increasing exponential when supply chains are transforming to real-time supply chains. Managing these flows requires careful planning, coordination and collaboration between different partners.

Finance flows constitute of credits, consignments and payments. Managing the finance flow is quite straightforward due to standards and norms that regulate and support monetary fluxes (Hadaya & Cassivi 2009, p.19). Material flows include raw materials, subassemblies, final products, material returns, servicing, recycling and disposals. Material flows in the supply chain are triggered by information flows, which move upstream the supply chain (Wu & Blackhurst 2009 p.109). Global sourcing has made it more complicated to integrate and coordinate material flows from multiple suppliers locating all the world and at the same time managing the distribution of final products through multiple intermediaries (Christopher 2011 p.13)

According to Hugos (2011, p.16-19) a supply chain constituting activities to turn raw materials into final products and deliver them to the ultimate customer. Even though all the supply chains basically are built to enable the flow of goods from the raw material supplier to the ultimate customer, the flow of materials and information are shaped by the location of the material and information decoupling points. The material decoupling point separates the forecast driven parts of the supply chain from the customer order driven parts of the supply chain. (Mason-Jones & Towill 1999) The material flow in the forecast driven parts of the supply chain is triggered by long-term demand planning which leads to stable flow of materials and the customer order driven parts of the supply chain is served from large inventories. When material flow is triggered by long-term forecast, the supply strategy is called “push”. The material flow in the downstream is triggered by the actual customer order and this type of supply strategy is called “push”. (Ahn &Kaminsky 2005). The location of the material decoupling point depends the final products and adopted supply chain strategy (Mason-Jones & Towill 1999). For example, project-based industries the material decoupling point is further in the upstream than process-based industries such as timber or pulp and paper.

The information decoupling point separates the part of the supply chain which has access to unmodified and undistorted marketplace order data from the part of the supply chain which relies on the forecast data (Mason-Jones & Towill 1999). Traditionally the material and information decoupling points have located on the same spot in the supply chain. However, Mason-Jones & Towill (1999) argued that most beneficial to the supply chain would be to place the information decoupling point as far upward as possible. This will minimize the risk of “bullwhip effect” where small demand changes close to customers will magnify downstream. This will cause excess inventories or out-of-stock phenomena.

Even though the material flow can be triggered by actual customer orders or demand forecasts, managing material flows in the whole supply chain is concerned to reduce the high costs associated with inventories and transportation by planning and coordinating the flow of material from suppliers to end customers as an integrated system (Christopher 2011, p.9-13). The integration of different supply chain stages is important since in the conventional supply chain each stage tends to be disconnected which will leads to sub-optimized performance due to increased buffer stocks and time lags. The outcome of this decrease responsiveness and higher total costs. To overcome this problem, the supply chain needs to be fully connected. Different entities in the supply chain become connected through shared information and aligned processes. (Christopher 2011, p.141) Figure 2 demonstrates how material decoupling point and information decoupling point can locate in the different part of a supply chain.

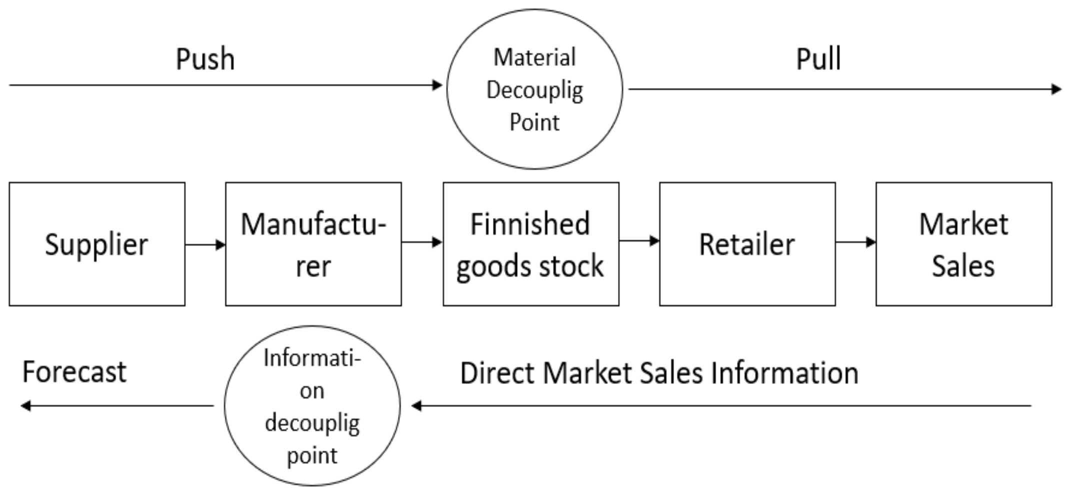

***Figure 2**. Material and information decoupling points (Adopted from Jones & Towill 1999).*

Sufficient and prompt information flow through the supply chain shorten the order cycles, enhance the responsiveness and visibility of the supply chain which ultimately translates to improved competitiveness and efficiency (Sezen 2008). However, the amount of shared information isn’t as important as timely, reliable and accurate information which can be used in decision making, forecasting and anticipating possible disruption in the supply chain. Kaipia (2009) emphasized the importance of matching the level of information sharing with the need of the organizations and the supply chain. Frequently shared and high volume of information benefit supply chains which are flexible for demand changes and have to deal with high level of uncertainty. On the other hand, if supply chains are inflexible for any changes in volume or product mix cannot benefit from frequent information sharing since they are not able to replanning their material flow for a short period of time. This type of supply chains benefits more from accurate information which can be utilized in advance forecasting models. (Kaipia, 2009) Wu and Blackhurst (2009, p.109) stressed the importance of understanding (1) what information flows there are in the supply chain, (2) the design of the information flow path in the supply chain and (3) how errors and disruption in information flow affects the material flow in the supply chain.

Information flows and their effects on the supply chain vary between different products, industries and applied supply chain strategy, but ultimately information is provided to support decision making. (Kaipia 2009) For example in project environments where customer preferences shape the final products, the volume of information can be significant and temporary nature of the supply chain means that many times the information sharing practices are poor or not existing. Good example of this type of project environment is a construction industry. Liu and Chua (2016) argued that in construction industry inefficient and unorganized information sharing creates waste that is causing unnecessary costs and delays in the construction projects. This is caused by fragmented nature of the construction supply chain and poor communication practices.

Digitalization can be one possible cure for poor information sharing and communication, but also it is important to manage relationships in the supply chain and building information sharing practices. As discussed earlier, SCM focused on the integration of business processes throughout the whole supply chain (Menzler et al. 2001; Coper et al. 1997). Integration of business processes means that the goals of different entities in the supply chain are aligned and there are transparency and trust among these entities. This also emphasis the importance of information sharing and relationships management in the supply chain.

2.1.4 Supplier relationship management

Lambert (2014, p. 2) states that SCM is really about the management of relationships in the network of organizations and these relationships are the" glue" that really connects the supply chain members. The supplier relationship management is the SCM process that provides the structure for developing and maintaining relationships with suppliers (Lambert and Schwieterman 2012). The reason why the management of supplier relationships is important is due to the global markets where companies are focusing on their core competencies and capabilities and everything else is outsourced. This means that much of the customer value is created outside the focal company and the overall performance depends greatly on the suppliers who are carrying out the outsourced work.

When companies decide suitable sourcing strategy, it is important to identify the key products and services that are critical for organizations success. Once key products and services have been identified, suppliers be categorized by using suitable criteria. Possible segmentation criteria can based on for example profitability, criticality, the supplier's technology capability and compatibility, necessary service level, volume purchased from the supplier, supplier's anticipated quality level or potential for co-create value (Lambert and Schwieterman 2012). Chosen criteria should meet specific need and goals of the company.

The Supplier Segmentation Matrix is a convenient strategic tool for segmenting the suppliers. It contains of four main segments which are: *Strategic*, *Bottleneck*, *Leverage* and *Routine*. The basis of the classification are the products and services the suppliers provide. Figure 3 presents supplier segmentation matrix adopted from Lambert and Schwieterman (2012).

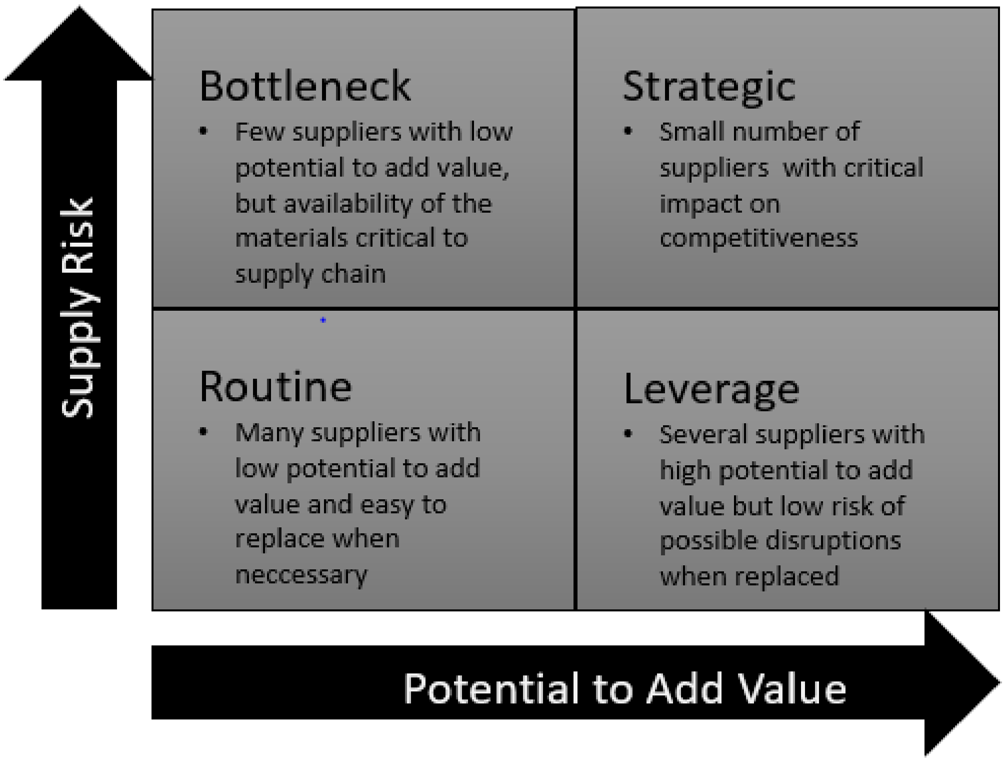

Figure 3. *Supplier segmentation matrix (adopted from Lambert & Schwieterman 2012).*

Categorizing suppliers is important in order to contrate resources to build strong relationships with those suppliers which are critical for organization's success (Teller et al. 2016) Relationships with suppliers can be divided in three different type of relationships: strategic, collaborative and transactional (Park et al. 2010).Transactional relationships are mainly for suppliers in Routine segments. Collaborative relationships are for Leverage and Routine segments and strategic long term partnerships are built with suppliers in Strategic segment. (Park et al. 2010) Lambert and Schwieterman, (2012) identified the following business objectives for the segments :

- Bottleneck: Supply quality and continuity
- Strategic: Profitable long-term growth for both parties
- Leverage: Cost savings and value maximization
- Routine: Simplicity and efficiency.

Level of integration with suppliers depends on the relationships in the supply chain and information sharing can promote further integration with suppliers. Regular information exchange between supply chain partners helps the supply chain to work as a single unit where materials flow seamlessly along the supply chain. (Li et al. 2005)

2.2 Project supply chain

2.2.1 Project management

A project is unique temporary endeavor to undertake to create products, services or results to the customer. Normally projects involves many interested parties or stakeholders, but a project always must have a primary customer which can be external or internal. Secondly, a project is always temporary with a definite beginning and a definite end provides a customer uniqueness. The success of the project is depends on the three primary constrains *time, scope* and *cost*. *Scope* outlines the boundaries of a project, related activities and resources and project deliverables. *Time* is the second constrains and it defines the project's schedule. *Cost* outlines the project's budget. These three constrains form the goals of the project. For example meeting the budget and time goals may require to decrease the scope or meeting time and scope goals may require to increase the budget. There are three other constrains that affect the ability to meet scope, time and budget goals: *quality, risk* and *resources*. (Swalbe 2015, p.5-8)

A project always needs well-defined objectives which are usually defined in terms of cost, scope and time (Kerzner 2017, p.2-3) The accomplishment of the project requires to carry out a sequence of interdependent tasks in a certain order. Some of the tasks can be accomplished simultaneously, but most of the tasks requires the accomplishment of previous tasks in a sequence before they can be executed. (Ala-risku et al. 2010) The interdependency of the tasks means that even a menial task can be critical if many other tasks are dependent on the accomplishment of this tasks. Therefore, special attention has to put on accomplishment of tasks on time since one task can delay the whole project. Furthermore, all projects involving uncertainty. The level of uncertainty varies between different projects, but in all project uncertainties need to managed (Swalbe 2015, p.5-8). If uncertainties aren't managed properly, it can realize to a risk which can prevent to meet the project's goals and has negative impact on the success of the project.

Every project has to have designated project manager who is responsible for the accomplishment of the project. According to the Kerzner (2017, p.4) project management is "the planning, organizing, directing, and controlling of company resources for a relatively short-term objective that has been established to complete specific goals and objectives." Project management encompassing the following phases: *initiating, planning*, *executing*, *monitoring* and *controlling*, and *project closure*. (Kerzner 2017, p.2-3; Swalbe 2015 p., 10) Figure 4 presents project management phases defined by Kerzner (2017, p.4).

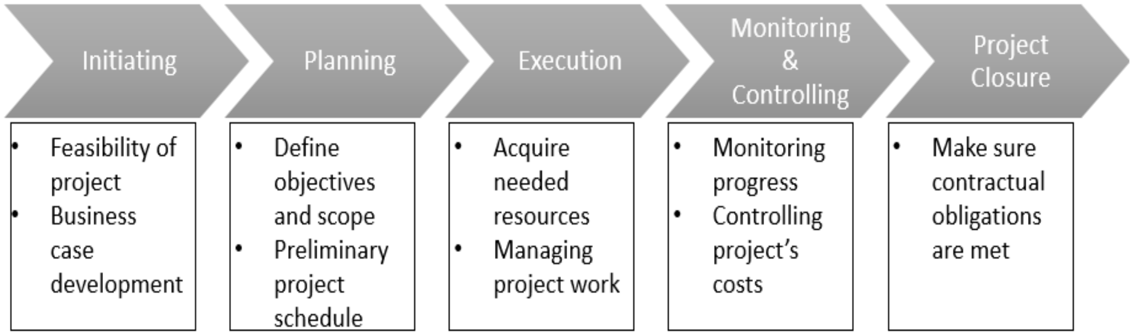

Figure 4. *Project management phases.*

Initiating phases including activities such as defining the project at broad level , investigating the feasibility of the project, preparing the documents to sanction the project and assigning the project manager. (Kerzner 2017, p.3) Furthermore, it is important to develop a business case for the project to argument why the project should be initiated, what are the main benefits and risks of the projects and how the project supports the organization's business strategy.

In project planning phase first thing is to define the objectives and the requirements of the project. Once these have been defined it is important to establish policies, procedures and programs for achieving the objectives (Kerzner 2017, p.21). It is necessary to distinguish between a project objective and a project requirement. A project objective is desired outcome, but a project requirement is a need to be fulfilled. Next thing is to have a clear definition of the project scope and brake down the scope into key milestones, resources and activities. After that, a preliminary project schedule can be created with key activities and milestones. Planning in project environment can be seen as a predetermined course of action to successfully execute the project and meet the defined objectives of the project.(Kerzner 2017, p.4-21)

Once a sound project plan has been put into place, next phase is project execution. These phases including acquiring needed resources to carry out the project as well as directing and managing project work. and communicating with different stakeholders in order to fulfill project's requirements. Monitoring and controlling phases occur parallel to the project execution phase and the purpose of this phase is to make sure that the project will be completed on time, on budget and fulfilling customer's expectations. The project can be closed when it has been delivered and all contractual obligations are met. The project closure including formal closure with finalized contracts, release of organization resources and documented lesson learned.

These aforementioned phases make up a project life cycle which provides the basic framework for managing the project (Kerzner 2017, p.3-5) Projects vary greatly depending on the project dimensions and the project deliverables. Project dimensions such as the size of the project, complexity and uncertainty affect the difficulty of managing the project. It is quite obvious that larger projects involve more resources and interlinked activities which bring challenges to project management. Larger projects can be more complex due to more people, resources and activities involved. However, project size doesn't directly link to more complexity. Vidal & Marle (2008) defined project complexity as "the property of a project which makes it difficult to understand, foresee and keep under control its overall behavior". In general, one aspect which makes project complex is the interdependency of elements within the project. In addition, projects always involve some degree of uncertainty which can be caused by undefined or unclear project goals, lack of information or unreliable information, novelty of project or technologies, constant changes in the project scope and other unpredictable factors. It is important to knowledge that project uncertainty changes over time and normally is higher in early phases of the project. (Jensen et al. 2006).

2.2.2 Supply chain management and project context

SCM related concepts such as just-in-time (JIT), vendor managed inventories, flexible manufacturing and mass customization are widely adopted and implemented in retail and manufacturing industries. The benefits of SCM are well understood in these industries, but many project-based organizations lagging behind in implementation of SCM practices. (Sanderson & Cox 2008; Morris & Pinto 2007, p. 226-235) Especially construction projects suffer from cost overruns or delays due to poor supply chain performance (Bankval et al. 2010) Adopting SCM practices and obtain supply chain integration have been suggested as a cure for poor performance. (Briscoe and Dainty 2005) Supply chain integration can be achieved by using collaborative and coordinating processes, technologies and practices among the supply chain partners (Vijayasarathy 2010). Practices that support supply chain integration are for example Information sharing, early supplier involvement, integration of business processes, cross-functional teams and information technology to support information sharing and business process integration. (Paulraj et al. 2006).

Furthermore, Morris and Pinto (2007, p.226) suggests that project-based organization should change their firm-focused approach to integrated supply chain approach. This means that project's goals should be broaden from individual company level to whole supply chain level to achieve value optimization for the project. Many supply chains are underperforming due to mismatch between products and supply chain configuration (Fisher 1997).

Hugos (2018, p.4) states the goal of SCM is to “achieve the best combination of responsiveness and efficiency in the supply chain to serve the market.” The best combination of responsiveness and efficiency depends on the market the supply chain is serving (Hugos 2018, p.164-168). The supply chain is configured on the basis of products it produces and the market is serves. Fisher’s (1997) demand contingency model aligned the product/market requirements with supply chain configurations. The model based on the assumption that there are two type of products, *functional* or *innovative* which match with two type of supply chains, *responsive* or *efficient*. Functional products are products which have high volume, little variation and are fulfilling the basic needs of consumers. Since there is very little variation, the barriers to market entry are normally low and competition is fierce. This forces companies producing and supplying functional products to operate with low product margin. Demand of functional products is usually predictable since the basic needs of consumers change very little over time. (Sanderson & Cox 2008)

Innovative products, on the contrary, have high product variety and demand is unpredictable due to newest of innovative products and demand isn’t yet established in the markets (Sanderson & Cox 2008). Innovations enables to limit the competitions and make it possible to gain better profits from the products. However, better profits can are usually short-lived since innovative products have relatively short life cycle and products margins erode over time when more competitive imitations enter the markets. (Sanderson & Cox 2008).

According to Fisher (1997) the strategic priority for companies selling functional products should be minimizing the physical supply chain costs. On the other hand, companies selling innovative products the first priority is to control market mediation costs. Physical supply chain costs are the associated with production, transportation and inventories (Fisher 1997) Market mediation costs are the costs associated with product obsolescence or out-of-stock. Hereby efficient supply chains are designed for efficient use of recourses, while responsive supply chains try to efficiently respond to changing market conditions. (Sanderson & Cox 2008)

Efficient supply chains are designed to produce and deliver products with lower costs than responsive supply chains. In order to achieve the benefits of efficient supply chain in full-extend, demand should be as predictable as possible and product variety as low as possible. This way products can be produced in large batches and there is need to keep very little inventories. On the contrary, when demand is unpredictable and product variety is high most suitable supply chain is responsive supply chain.

Basnet & Seuring (2016) stated that external environment induces contingences and supply chain configurations are designed to response these contingences. A set of supply chain configurations make up a supply chain strategy. (Basnet & Seuring 2016) Therefore, product contingencies translate to a supply chain strategy. There are two well recognized supply chain strategies in the literature based on two philosophies: lean thinking or agile thinking. (Sanderson & Cox 2008) The core of lean philosophy is eliminating non-value-added activities which are considered as "waste". Lean, is applicable in many supply chains, but especially suitable for the kind of supply chains seeking cost reductions and efficiency. Therefore, adopting lean strategy in the supply chains producing functional products is very beneficial. Agility on the other hand, is a strategy to gain capabilities and competencies to quickly respond market changes such as demand fluctuation, product variations or disruptions in the supply chain.

Fisher's (1997) contingency model wasn't developed for project environment where demand is low and complexity and uncertainty is high. However, in some extent it can be used to match the project with most suitable supply chain type. According to Morris and Pinto (2007, p. 233) "the customer is most important value driver in project supply chain management." Ultimately it is customer's definition and perception that determines what elements create value in a project. (Morris & Pinto 2007, p. 233) If the customer values price, all the activities in the supply chain should be focused on efficiency and eliminating waste. On the other hand, if the customer values completion of the project on time and ability to respond quickly to project scope changes, supply chain-related activities should be geared to satisfied these needs. (Morris & Pinto 2007, p. 233-234) Therefore, both lean and agile supply chain strategies are in some extent suitable for projects, but especially uncertainty, complexity and low volume in projects bring challenges to fully adopt lean philosophy. Lean strategy is designed for industries where demand is stable and predictable. That is not the case in project environment where uncertainty is can be substantial high, especially in the beginning of the project. The nature of uniqueness and complexity of projects mean that there is unlike two identical projects so standardization is not possible as far it is possible in manufacturing industries. All these aspects lead to conclusion, that in overall, agile supply chain could be more suitable strategy in general for the projects. But, ultimately project's goals (scope, time and cost) shape the most suitable supply chain strategy.

The structure of supply chain can be also determined by the location of the decoupling point. The customer order decoupling point (CODP) separates the part of the supply chain which respond directly to the customer order from the part of the supply chain which forecast the demand. CODP can locates at finished goods in the distribution centers (Make to stock), at sub-assemblies in within the assembly process (Assemble to order), at the purchased goods (Make to order) or at the product design stage (Engineer to order). (Gosling & Naim 2009) ETO based supply chains allow customer fully customize products and product are designed to meet customer's unique requirements. (Stavrulaki & Davis 2010) Therefore ETO supply chains many times operate in a project environment where the products are tailored made and new orders begin with engineering stage. Since the customer order penetrates far in the upstream of the supply chain, lead times in ETO-based supply chains tend to long which is why ETO supply chains should focus on reduction of lead times and increase supply chain visibility (Stavrulaki & Davis 2010).

2.2.3 Project supply chain characteristics

A supply chain in a project environment can be called as a "project supply chain". Project supply chains are greatly affected by the type of products delivered in a project and a project scope. However, there are some distinguishable project supply chain characteristics that are present in project supply chains. These characteristics are presented in the Table 1 below.

***Table 1**. Project supply chain characteristics*

Project Supply Chain Characteristics	
Characteristics	**References**
Small number of customers and customers' strong influence on final products	Pesämaa et al. 2009; Kristianto et al. 2015
Engineer-to-order and pull-driven supply chain	Kristianto et al. 2015; Behera et al. 2015
Low volume and complex products	Sanderson & Cox 2008
Fragmented supply chain and temporary nature of the supply chain	Ala-Risku et al. 2010; Behera at al. 2015
Uncertainty and complexity	Ala-Risku et al. 2010; Thunberg et al. 2017; Swalbe 2015, pp.2-7
Overlap of engineering and project execution	Vrijhoef & Koskela 2000; Atkinson et al. 2006
Involves multiple stakeholders and suppliers	Behera et al. 2015; Xue at al. 2007
Low degree of supply chain integration	Thunberg et al. 2017; Vrijhoef & Koskela 2000

Customers are the driving force behind every supply chain, but this is even more evident in project supply chains where customers have strong influence on final products, their physical attributes and functionalities (Behera et al. 2015). Furthermore, customers in project context are normally organizations, institutions or governments and relationships are based on complicated contracts which determine the responsibilities of different parties involved in the project. (Aloini et al. 2015)

Engineer-to-order supply chains are common in large and complex projects where products are highly affected by customers' specifications and requirements. These type of projects are common in construction and capital goods sector. Engineer-to-order supply chains customer orders penetrate the design phase and lead times of the products are significantly longer than make-to-stock type of products. (Gosling & Naim 2009; Stavrulaki & Davis 2010) The overlap of engineering and production is also common in a project supply chain where the exact material requirements aren't clear until quite late in the project (Vrijhoef & Koskela 2000). Supply chains in the project-based business are struggling with the timing of material requirements arise from the interdependencies of the project tasks which are performed in sequence or simultaneously and are using the same resources. If one task is delayed, it will affect the tasks dependent on that particular task and resources and material may need to reallocate. (Ala-Risku et al. 2010) This means that even one delayed material can delay the whole project. This also emphasis the importance of managing and coordinating material flows efficiently in the project supply chain to make sure all the materials arrive on time and the quantities are correct.

Products in the project supply chains are normally low volume and complex products which have unpredictable and uncertain demand (Sanderson & Cox 2008). Therefore material flows in the project supply chain are triggered by the actual customer order instead of forecast and inventories have no significant role in this type of supply chain since CODP locates in the design phase (Gosling & Naim 2009).

The degree of information sharing and what type of information is shared vary between different type of supply chains. In make-to-stock supply chains the material flows are coordinated through demand forecasts and it is important that these forecasts anticipate the demand as accurately as possible. The information exchanged between different parties in this type of supply chain is related to customer demand data and customers' buying behaviors. On the other hand, ETO supply chains the information is related to a specific customer order and efficient dissemination of customer order related data and responsiveness are the main concern. (Kaipia 2009; Stavrulaki & Davis 2010) ETO supply chain should maintain high level of flexibility in production and logistics processes to achieve agile capabilities (Stavrulaki & Davis 2010). Agile supply chain support the quick response to changing customer needs and requirements which can be changed also during project life cycle. Furthermore, the key elements of supply chain agility are focus on reducing lead times and improve the supply chain visibility. (Stavrulaki & Davis 2010).

Many project supply chains have suffered from poor performance and poor real time supply chain visibility, resulting delays in the project implementation and cost overruns. This has been the case especially in the construction sector. (Behera et al. 2015), (Liu & Chua 2016) The main factors caused by less than outstanding performance have been identified as lack of coordination and communication between supply chain participants, adversarial contractual relationship, lack of customer-supplier focus, priced based supplier selection, inefficient use of technology and poor information sharing practices (Cox and Ireland 2002; Liu & Chua 2016). Information sharing in the project supply chain is the key to strong performance because inefficient and unorganized information sharing practices generates a lot of waste (Aloini et al. 2015; Liu & Chua 2016). This doesn't only mean the exchange of information between project team members, project phases and within the company, but also sufficient dissemination of information throughout the whole supply chain. However, temporary nature of the supply chain and adversarial contractual relationships are the main obstacles for deeper supply chain integration and sufficient information sharing. Therefore, relationships with the key suppliers should be manage to closer partnership where there are continuity beyond one project and common information practices can be put into place. Information sharing throughout the supply chain is also important to maintain agility and flexibility of the supply chain.

The project supply chain's main characteristics can be defined as low volume, high complexity and uncertainty of product demand, contractual based relationships, temporary supply chain structure (supply chain structure can vary based on the project), low degree of supply chain integration. Project supply chain involves at least the following members: the principal contractor who is responsible of management of the project, suppliers and subcontractors and the customer (Parrod et al. 2007). In addition, project supply chains normally involve many suppliers and subcontractors so the principal contractor may have very little control over the whole supply chain.

2.2.3 Information and material flows in project supply chain

Material flows have huge impact on project supply chain's performance. Firstly, materials costs make up significant percentages of total goods capital project costs. Secondly, multiples studies indicate that incorrect materials and materials delays make up to 50 percent of project delays and cost overruns (Caldas et al. 2015, cited in Shash & AbuAljana 2021; Liu & Lu 2018).

Project supply chains are pull-driven which means that the actual customer order triggers the main material flows. Material flow coordination in the project supply chain is challenging especially when the design and manufacturing phases overlap. This means the material requirements aren't known precisely when manufacturing commences and flexibility is required to adapt the material changes (type of material, quantities, lead time) (Stravrulaki & Davis 2010). Furthermore, the timing of material requirements depends on sequence of interdependent tasks which means that the order in which materials are shipped can be crucial. (Ala-Risku et al. 2011)

Since many projects based on ETO supply chains, the CODP locates very far in the design phase. The products are customized and engineered to match special customer requirements and there are very little standardized subassemblies and components to keep on stock. Therefore, the impact of inventories is very little to the business and main inventories are in a raw material and a commodity level (Stravlula & Davis 2010).

In project supply chains customer sites are many times located far away from the production and materials are shipped directly from suppliers to the customer site or via consolidation points (Helo & Shamsuzzoha 2020). Also the supply chain network vary project to project due to different scope of supply and the customer site locations. The material shipments in the project context are very schedule dependent or materials belong to certain work phase. Helo and Shamsuzzoha (2020) emphasize the importance of material tracing and tracking system in project business where customer sites can locate far away from the production sites. If materials cannot be traced, there is no certainty that materials have arrived at the site and it can be easier just re-order the materials. Furthermore, manual material flow control such as spreadsheet applications are flawed for inconsistent material flow registrations and are arduous to keep updated (Ala-Risku et al. 2011)

Project supply chains involve a lot of shared information among the supply chain members since products are complex and customer requirements affect greatly on the final products. Information sharing and communication can be also major cost driver in the project supply chain if majority of information is travelling through an unorganized and inefficient fashion. Setting up proper information sharing practices can be difficult due to fragmented and temporary nature of supply chain. This leads to loosely connected supply chains where there is a little motivation to set up a common information sharing practices. (Liu & Chua 2016) Lack of real-time information leads to poor visibility in the project supply chain which makes it difficult to anticipated possible disruptions and delays. Furthermore, high volume of shared information can cause inefficiency if the project supply chain cannot process and utilize shared information in the decision making (Kaipia 2009).

Most of the information disseminates in project supply chains are related to changes in design, schedule, production and shipment of materials (Chen et al. 2021). Project supply chains consisting many times multiple layers of suppliers and subcontractors which aren't directly contacted with the principal contractor (Parrod et al. 2007). Since project supply chains involves a lot of suppliers in many layers, it is crucial that information disseminates quickly between supply chain members. Supply chain integration and prompt information sharing can lead to better flexibility and agility in the supply chain which ultimately improves the performance of whole supply chain (Hicks et al. 2000; Gosling & Naim 2009). Table 2 present obstacles for efficient information sharing and material management found in the literature.

Table 2. *Obstacles for sufficient information sharing and seamless material flows.*

Lack of trust between supply chain members	Bankval et al. 2010; Liu & Chua 2016; Thunberg et al. 2017
Temporary nature of supply chain	Bankval et al. 2010; Liu & Chua 2016; Ala-risku et al. 2010
Different information systems and lack of interoperability	Yu et al. 2018; Liu & Chua 2016
Lack of coordination between contractor and suppliers	Thunberg et al. 2017
Too many suppliers and fragmented supply chain	Liu & Chua 2016; Behera et al. 2015
Spreadsheets, emails and manual data collection	Braghlia 2014; Ala-Risku et al. 2011; Aloini et al. 2015
Insufficient procurement planning and manual material movement processes	Azambuja & O'Brien 2009; Ala-Risku et al. 2010
Item identification and on-site material storing	Ala-Risku et al. 2010
Poor real time supply chain visibility	Liu & Chua 2016; Behera et al. 2015
Material traceability and tracking	Helo & Shamsuzzoha 2020

Thunberg et al. (2017) categorized on-site production problems into four categories: *material flow issues, external communication, internal communication* and *complexity*. Since the emphasis is on the whole project supply chain, external and internal communication categories can be broaden to issues with information sharing. Furthermore, complexity derived from the nature of the project since projects involves a lot of uncertainty and uniqueness. Therefore, complexity is directly linked to the project supply chain characteristics. Figure 5 below presents how the found obstacles from the literature have been categorized in three different categories: *material flow, information sharing* and *project supply chain characteristics*.

Figure 5. *Categorization of obstacles for efficient information sharing and material flow management.*

The performance of project supply chains depends heavily on how efficient information sharing and seamless flow of materials from raw material suppliers all the way to the construction site. The timing of material requirements depends on interdepended project tasks which are performed in sequence and delays in one task affects the other tasks dependent on it. This means that the arrival of materials on time is crucial in order to meet the project schedule. (Ala-Risku et al. 2010) Tracking and tracing capabilities in the project supply chain can enhance the real-time visibility of the material flow and support the successful project delivery (Helo & Shamsuzzoha 2020). Furthermore, material movement is still in many cases control by using spreadsheets which is error-prone and inefficient. Poor supply chain visibility make it difficult to anticipate possible delays and disruptions in the supply chain which results delays in project implementation and revenue recognition (Behera et al. 2015; Azambuja & O'Brien 2009)

Temporary nature of supply chain and fragmented supply chain are clearly obstacles for sufficient information sharing. However, these obstacles derive from the project supply chain characteristics.

2.3 Digitalization in project supply chain

2.3.1 Digital Supply Chain

Digitalization has been identified as a major trend affecting the society and the business both in short and long term. (Tihinen & Kääriäinen 2016) There is not one clear definition for the word "digitalization", but for example Brennan and Kreiss (2014) define digitalization as "the adoption or increase in use of digital or computer technology by an organization, industry, country, etc." Digitalization is a phenomenon that has changed the way people communicate and interaction with their surroundings. (Büyüközkan & Göçer 2018) There is hardly any aspect of life which hasn't been affected by digitalization and supply chains aren't an exception. New emerging digital technologies are paving the way toward more interconnected activities and more transparent flow of information in the supply chain (Seyedghorban et al. 2020).

Kache and Seuring (2017) present multiple opportunities of supply chain digitalization that include increased access to information, optimized logistics between companies in the supply chain, better supply chain visibility and transparency through real time information access and control, efficient inventory management, increased end-to end integration and connectivity in the supply chain. Büyüközkan and Göçer (2018) state that digitalization "enables the evolution of the next generation of supply chains offering both flexibility and efficiency." They also claim that traditional supply chain consists of discrete, siloed steps and by transforming a traditional supply chain into the digital supply chain, it is possible achieve a fully integrated system that runs flawlessly (Büyüközkan & Göçer 2018). A Digital Supply Chain (DSC) refers to an intelligence, customer centric and data-driven network that leverages new approaches with innovative technologies and information systems to generate new form of revenue and business value (Büyüközkan & Göçer 2018; Kinnet 2015; Ageron et al. 2020). Büyüközkan and Göçer (2018) have identified ten main features that DSC strive to achieve:

- Speed
- Flexibility
- Global Connectivity
- Real-time inventory
- Intelligence
- Transparency
- Scalability
- Innovative
- Proactive

- Eco-friendly

The speed at which products are delivered to the market is crucial. Companies are looking innovative ways to deliver products quicker to the customers such as using drones, 3D printing or autonomous vehicles. Digitalization will also enhance the flexibility of the supply chain by efficiently using the information collected and modelled. (Büyüközkan & Göçer 2018) Furthermore, companies in the supply chain can gain competitive advantage by a global end to-end supply chain connectivity through digitalization. (Porter & Heppelmann 2015) This end-to-end connectivity together with transparency throughout the supply chain enable better visibility for possible disruptions in the supply chain and proactive actions against anticipated issues, prior they occurrence (Büyüközkan & Göçer 2018).

Even though digitalization has opened doors for countless opportunities in supply chains, there are issues and challenges related to implementation of DSC. Information sharing is the corner stone of DSC, but sometimes companies are reluctant to share information with other members of the supply chain. (Büyüközkan & Göçer 2018) This is due to lack of trust between supply chain members and transaction-based relationships in the supply chain. Furthermore, different information systems and technologies used in the supply chain prevent sufficient information sharing and end-to-end supply chain data access (Yu et al. 2018). This has a lot to do with the type of relationships nurtured in the supply chain and how complex is the supply chain.

Project-based supply chains tend to be more complex and longer (multiple tiers) and therefore, the end-to-end visibility of the supply chain is much more difficult to achieve. Furthermore, in many project-based industries such as construction industry, many relationships are contractual based and there is a lack of coordination and communication between the members of the supply chain (Bankvall et al. 2010). However, integrating multiple data sources for building visibility and transparency in the supply chain, will accelerating decision making loops in projects and ultimately leads to better project supply chain performance (Helo & Shamsuzzoha 2020)

2.3.2 Impacts of digitalization for supply chains

Parviainen et al. (2017) have categorized the impact of digitalization for an organization into three different groups present below.

- Internal efficiency: digitalized business processes improve efficiency, quality and reduce manual work.
- External opportunities: digitalization creates new business opportunities and new form of revenues in existing business domain
- Disruptive changes: digitalization changes the whole operating environment of the business and creates new business and can make company's current business obsolete.

Digitalization biggest impact for businesses are disruptive changes which change the whole business and the revenue models. Good examples are Netflix, Uber and Airbnb and how they have utilized digitalization in their business to create competitive advantage and disrupting whole industries. (Parviainen et al. 2017) However, to benefit from disruptive changes caused by the digitalization may require to rethink the whole business models of the company and reform the company's strategy to build on digital capabilities. Internal efficiency and external opportunities are more tied to operational and tactical level and therefore more achievable in short term. Many scholars have discussed the huge potential of digitalization for supply chains, but most of the potential hasn't been realized yet (Ageron et al. 2020; Hartley & Sawaya 2019). Table 3 presents the advantages of digitalization for supply chains gather from publications and scientific articles. The table includes three groups of the impact of digitalization (internal efficiency, external opportunities and disruptive change) and the advantages are matched with suitable impacts of digitalization.

Table 3. *Advantages of digitalization in supply chains.*

Advantage	**Internal efficiency**	**External opportunity**	**Disruptive Change**	**Author**
Accurate and holistic decision making	X	X		Ageron et al. 2020; Dinter 2013
Reduced supply chain lead times and flexibility in supply chain design	X			Segars & Grover 1995
Transparency, visibility and interoperability	X			Helo & Shamsuzzoha 2020
Automated processes	X			Korpela et al. 2017
Accurate demand forecasting, enhanced responsiveness and proactive problem solving.	X			Ageron et al. 2020; Hanifan et al. 2014
Customer-centricity and personalized customer experience		X	X	Büyüközkan & Göçer 2018; Seyedghorban et al. 2020
Easier information sharing and leveraging new technologies such as Big Data, Data Analytics and Cloud Computing.	X	X		Büyüközkan & Göçer 2018; Gunasekaran et al. 2017; Preindl et al. 2020
Efficient integration of people, technology and processes	X			Hanifan et al. 2014
Organizational flexibility and supply chain scalability	X	X		Hanifan et al. 2014
Improved responsiveness and agility	X			Hanifan et al. 2014; Seyedghorban et al. 2020

As Table 3 indicates, most of the advantages of digitalization will impact on internal efficiency of the supply chain and therefore the focus will be on the advantages which will improve the internal efficiency. Hanifan et al (2014) present four key attributes of a modern supply chain which are: *Rapid*, *Scalable*, *Intelligent* and *Connected*. Speed is the one of the most influential driver of modern supply chain and not only products changing more rapidly but also companies need to adjust their processes and resources faster to match the market's needs. DCS will enable shorter supply chain lead time, enhanced responsiveness and proactive problems solving. Furthermore, when supply chain is imbued with digital technology enabled connectivity and intelligence, supply chain scalability up or down become more attainable due easier process optimization and duplication (Hanifan et al. 2014). DSC tends to be also more connected due to easier information sharing and efficient integration of people, processes and technology. Lastly, DSC are data-driven value chains which leveraging digital technologies such as Cloud Computing, Big Data and Data Analytics to turn data into valuable information used in decision making and demand forecasts. Ultimately more digitalized supply chain will lead to increased efficiency and responsiveness which is also the goal of supply chain management. (Hanifan et al. 2014; Büyüközkan & Göçer 2018; Ageron et al. 2020)

Despite the fact that the digitalization can greatly affect the performance of the supply chain, the digital transformation of supply chain can be a challenging task. Building the digital transformation on digital technologies without a clear roadmap how digitalization and new technologies can be utilize best to achieve supply chain goals will most likely lead to poor results (Hartley & Sawaya 2019). Adapting new digital technologies always requires funds and investments and if it not clear what kind of digital technology capabilities are needed in the supply chain, the cost of digitalization can increase the possible benefits. Furthermore, the digitalization has disruptive impact on transactional activities in the supply chain due to machine learning and automation. The digitalization will challenge existing organizational structures and requires new type of management skills to integrate digital technologies, business strategies and IT strategy (Hartley & Sawaya 2019). Obviously employees' resistance to change in the organization is the one of the biggest challenges for the digitalization of the supply chain. In order to get the full potential of digitalization and digital technologies, the digitalization strategy needs to be implemented in every level of the organization and beyond that in the whole supply chain. Especially the digitalization in the whole supply chain is very tricky since supply chains involve many different type of organization and the degree of digitalization vary between organizations.

The issues of data security have been addressed, especially with cloud-based systems such as cloud-based ERP software where servers locate off-premises (Hartley & Sawaya 2019). In addition, in the digital supply chain the volume of gathered information can be huge and who owns the data, who can utilize it and how accurate the data is, are relevant questions. The lack of interoperability of existing IT systems is huge barrier to overcome in order to really achieve fully connected and scalable supply chain. Every organizations have their own IT systems which rarely communicated which each other and information is kept in silos inside these systems. Fully connected supply chain would require huge investments in IT systems and software which can communicate each other, and that is not reality in many supply chains due to lack of funds and willingness. The interoperability of IT systems across the organization boundaries requires commitment and common standards between supply chain members to fully integrate the systems and business processes. Therefore, the focal company should firstly strive to better interoperability of IT systems with key partners in the supply chain who are crucial to the business. (Korpela et al. 2017; Schwertner 2017; Shao et al. 2006)

2.3.3 Digital technologies and applications

The digital transformation of the supply chain wouldn't be possible without enabling technologies. However, before adopting new emerging technologies into daily-base supply chain processes, there should be a clear road map how the exploit digitalization to achieve the supply chain's goals. Once there is a clear roadmap how to exploit digitalization in the business, can be taken closer look onto the technologies.

Hartley and Sawaya (2019) studied how robotic process automation (RPA), artificial intelligence (AI)/machine learning (ML) and blockchain can improve supply chain business processes. They concluded that RPA technologies are often the first step of digital transformation since RPA is relatively easy to deploy by using software bots and it can be applied to many different kind of processes which include repetitive tasks (Hartley & Sawaya 2019). Furthermore, RPA technologies require relatively low investments and payback time is typically less than 12 months (Wright et al. 2018).

AI is an intelligent systems with the ability to interpret external data and learn from it. According to Jarrahi (2018) three common elements that extend AI cognitive utilities are: ability to process human languages, machine learning and machine vision. ML is a subset of AI that uses algorithms to analyze patterns in data and develop intelligent solutions based on the patterns (Hartley & Sawaya 2019). There are multiple applications of ML in supply chains such as: demand planning and forecasting, optimizing routing for deliveries, scheduling of warehouse pick processes and supplier evaluation and selection (Hartley & Sawaya 2019; Ni et al. 2019). Amount of data available in supply chain are increasing all the time and ML creates opportunities for improving supply chain decisions. Even though many organizations see the potentials of ML, very few has utilizing it in decision making and supply chain operations (Hartley & Sawaya 2019). The deployment of ML is more complicated than RPA since many companies doesn't have required knowledge and expertise to develop and deploy ML technologies in supply chain processes (Hartley & Sawaya 2019).

Blockchain is a distributed ledger technology that is well known for its use in cryptocurrencies, but it has received also a lot of attention for it potential to increase the transparency and trust in the supply chain (Hartley & Sawaya 2019). The three main properties of the blockchain technologies are: decentralized, verified and immutable (Hackius,& Petersen 2017). Blockchains are decentralized because they are run by the members of the network instead of centralized authority and infrastructure. All added transactions to the ledger are shared with blockchain's peer-2-peer network for verification and auditing. The transaction is verified when the majority of members sign the transaction using public-private-key cryptography. One or more transactions make up a new block in the chain and all the network members can verify transactions in the block. If there is no consensus on the validity of the new block among the network members, it will be rejected. Altering transactions on the block after verification is almost impossible since this would require to alter the local records on the most of the network members' devices and also to alter the cryptographic hashes down the chain (Hackius & Petersen 2017).

A blockchain can be private or public but typically supply chain blockchain platforms are private. Private blockchains are accessed by only authorized user who has been granted permission (Gupta 2017). Blockchain's ability to guarantee the reliability, traceability, and authenticity of information can benefit the supply chain, especially in the cases where there is a lack of trust between supply chain members. Some of the prominent applications for the supply chains are: automated transactions through smart contracts, material tracing and tracking, identify counterfeit products, a platform for data storing immutable and reliable way and more efficient document sharing and approval process with international shipping (Hackius & Petersen 2017; Hartley & Sawaya 2019). Even though the possible benefits are well recognized in academia, the adaptation of blockchain technologies in the supply chains lagging behind. The study conducted by Hackius and Petersen (2017) indicated that the main barriers for blockchain adaptation are regulatory uncertainty, lack of joint venture in blockchain adaptation, lack of technological maturity and lack of acceptance in industry. According to Hartley and Sawaya (2019), it appears that the perceived value of blockchain is limited to the cases where there are high level of supply chain visibility needed or there is complex document flow among the supply chain members.

Cloud computing is offering practically unlimited computing resources which can be quickly scaled up or down on demand (Hugos 2018, p. 118). There is no need for long-term commitment since the resources are immediately available and only so long as needed. The cost of cloud services depends on the amount of usage and there is no huge investments required (Hugos 2018, p. 118). There are three main service models in cloud computing: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) (Ryan & Loeffler 2010). SaaS model provides on-demand software applications over the Internet and an organization using SaaS applications doesn't have to maintain and install the software on-premise data centers or computers. IaaS model allows organizations to outsource computing infrastructure from the cloud service provider. The hardware and servers are at the cloud service providers premises and customers are paying for on-demand computing resources. PaaS is the common cloud based service to test, run, develop and deploy applications. In PaaS model, the cloud service provider "provides the operating system, servers, database management systems, middleware, business intelligence and analytics tools as well as the software development tools that an organization may require to develop custom applications. The organization has the control over the developed custom applications but the service provider maintains and administers the operating system, servers and the computing platform needed for running the application. (Tadapaneni 2017)

Cloud-based Enterprise Resource Planning (ERP) system is SaaS based service which has some benefits over on-premise ERP systems including lower investment and implementation costs, enhanced business intelligence and analytics capabilities, easier remote access and centralized security and controls (Warnock 2018). However, cloud-based ERP has raised concerns about the data security since data is stored in external hardware and servers. A Cloud portal can be integrated with multiple other technologies such as QR codes, radio-frequency identification (FRID) technologies, blockchain and Internet of Things (IoT) based technologies.

QR code is two dimensional barcode which can store significantly more information than traditional Bar Code and it can contain numbers, characters and images (Qing 2019). One of the biggest advantages of QR codes are they readability and amount of information can be stored in. A smartphone with a camera is only device needed for retrieve information and register events (Peltokorpi et al. 2020). QR codes can be generated by using free on-line QR code generators and can be printed out to a plain paper by using a normal printer (Vazquez-Briseno et al. 2012). There are multiple commercial applications for QR codes such as wireless advertising and marketing, wireless trading, product information tracking and checking, mobile security, mobile customer and product verification and wireless payment (Vazquez-Briseno et al. 2012)

FRID technology based on radio waves to store and retrieve information from an identification chip (Vazquez-Briseno et al. 2012). There are three main components needed in a FRID system: a FRID reader, FRID tags and application software for processing the information. A FRID tag contains writable memory and the size of the memory depend on the type of a tag. FRID system can cover distance of less than 100 meters. There are several commercial applications for FRID technology such as security, access control, transportation and tracking of the supply chain. (Vazquez-Briseno et al. 2012).

Helo and Shamsuzzoha (2020) developed Real-Time Supply Chain (RTSC) system for decentralized project logistics. RTSC system was built on the following technologies:

- Blockchain: to verify the authenticity of transactions from the supply chain
- RFID technology and barcodes: to create logistics related transactions
- IoT tracking device interface: real time material tracking
- User interface on a cloud portal: data visualization

IoT enabled technologies can significantly improve the visibility and agility of supply chains through real-time information exchange. IoT incorporates advance technologies to facilitate applications, devices, and objects that are communicating between each other through the connected networks (Tarouco et al. 2012).The enabling technologies of IoT consist of four major layers:

- Data Collection by using FRID and sensors
- Data transmission process that supports wire and wireless data transmission networks
- Service layer that uses middleware to integrate services and applications
- Interface layer that provides the user interface

According to the Abdel-Basset et al. (2018) the main benefits of IoT to supply chains are: enhanced management of inventories, real time supply chain management and maximized transparency of logistics. Especially FRID based technologies and sensors are important enablers of IoT architecture since they enable huge amount of information exchange in real-time which is the cornerstone of functional IoT solution (Abdel-Basset et al. 2018).

2.3.4 Digital tools to enhance project supply chain's information and material flows

Material and information flows have significant impact on the performance of the project supply chain (Liu & Chua 2016; Liu and Lu 2018). However, multiple obstacles for efficient information and material flows in the project supply chain have been identified in previous chapter. Benefits of digital supply chain have been identified as increased access to information, optimized logistics between companies in the supply chain, better supply chain visibility and transparency through real time information access and control, efficient inventory management, increased end-to end integration and connectivity in the supply chain. These benefits can be directly linked to more efficient information and material flows in the supply chain and therefore digitalization can have a significant impact on project supply chain's performance. Table 4 presents the identified obstacles for efficient information and material flows in the project supply chain and what digital technologies can overcome some of these identified obstacles.

Table 4. *Digital technologies to enhance material and information flows.*

Poor real time supply chain visibility	QR code, FRID technology and IoT
Material tracing and tracking	QR code, FRID technology, Barcodes
Insufficient procurement planning and material movement processes	RPA and QR codes
Different information systems and lack of interoperability	SaaS
Spreadsheets, emails and manual data collection	RPA and SaaS
Material identification and on-site storing	QR code, FRID technology and SaaS

One of the biggest benefits of digitalization is better supply chain visibility through real time information access and control. QR codes and FRID technologies enables better visibility on material flows in the supply chain. QR codes and FRID-tags can be used to identify, trace and register materials and material movements in the supply chain. These technologies are suitable for recording logistics transactions and therefore replacing manual data entries. (Helo & Shamsuzzoha 2020) However, QR code and FRID technologies are one distinguishing difference: FRID technology reads one-to many and QR code reads one-to-one. This means that QR code can record one transaction at a time, but FRID technology enables multiples transactions at a time by using special reader generates strong electromagnetic field. However, to set up a QR code based material movement tracing system is much cheaper than FRID based since QR codes can be printed and read by using standard smartphones. (Peltokorpi et al. 2021) QR codes can be also used to track order status at subcontractor's facilities when QR-labels are attached on the manufactured parts. This can replace spreadsheet based progress reports which can be unreliable and cannot provide real time information access. QR codes are normally linked to cloud-based system where to monitor order status. (Peltokorpi et al. 2021)

Spreadsheet and manual data collection are still very relevant in many project supply chains (Braghlia et al. 2014). Collecting data on spreadsheets can be very laborious and prone to error due to manual data entries. This is the case especially when amount of collected information is huge and it has to be updated frequently. This will lead inevitably outdated data on the spreadsheets. Furthermore, e-mails represent a very common communication channel in every project supply chains. E-mails problem is that they can be ignored for long period of time which can cause significant delays in the project. (Braghlia 2014) Another problem with e-mails are their scattered and fragmented nature of information. The information can be scattered into multiples emails and this information can be accesses only very limited amount of people. RPA technology can be used to automate whole process or part of it. There are various of software bots which can be used to automated data collection or copying information from one source to another. Email processing requires a lot of employees' time and software bots can be used to extract information form email, send automatic reply, save email's attachments to an certain place or automatically share documents with suppliers(Hartley & Sawaya 2019). RPA are relatively easy to deploy since they don't normally require any changes existing IT infrastructure. Some of the leading RPA providers are Automation Anywhere, UiPath and Blue Prism (Hartley & Sawaya 2019). Microsoft has also launched they own RPA software called Power Automate which can be integrated to Microsoft's operating systems and require very little programming skills (Microsoft 2021).

Different information systems and lack of interoperability are huge obstacle for better material flow coordination and real time information exchange in every supply chain. In the project supply chain this is even more evident since supply chains are involving a lot of stake holders and suppliers who are loosely connected to each other and supply chain network can be formed only temporary to serve one particular project. This means that suppliers aren’t willing to invest a lot of money to align their IT systems with the main contractor. Information stored in the cloud enables better information access and cloud-based software (SaaS) offers cost-efficient way to align processes across the organizational boundaries (Hartley & Sawaya 2019). Furthermore, cloud-based applications can be integrated with other technologies such as QR codes, IoT, FRID and blockchains. One of the biggest benefits of cloud-based services is low investment costs since payment is based on payment per use. Therefore cloud-based services are especially for smaller companies which doesn’t have the capital to invest expensive in-house software.

3. CASE COMPANY INTRODUCTION

3.1 Background

The case company name is Nepean Conveyors Oy and its headquarter locates in Hollola Finland. The history of the company started in early 1960s when Murkauskonesuunnittelu Vartiainen Oy was founded. Company's name has changed many times due to mergers and acquisitions. Even though the company has been owned by multiple organization throughout its history, the brand Roxon is carried along since 1974 and has been well recognized among miners in the Nordics. Currently the company is owned by Australian Nepean DNA which has specialized in mining equipment and industrial manufacturing. Once Nepean DNA acquired the company, the name was changed from Sandvik Mining and Construction to Nepean Conveyors Oy.

Nepean Conveyors Oy operates in bulk material handling business and the business is divided into three business units: Systems, Components and Service. Systems is focused on bulk material handling equipment and turnkey projects mainly for the mining sector. The component division is delivering components for bulk material handling equipment and service division is servicing and overhauling equipment in Finland and Sweden delivered by the company or its competitor and selling spare parts for its equipment globally.

The main market areas are the Nordics, Russian speaking countries and South-America. The number of employees at the moment is 93 and company's revenue in fiscal year 2020-2021 (July 20-June 21) was a little bit over 30 million euros. The company's main location is in Hollola Finland, but the company has facilities in Kemi, Lappeenranta, Kuopio and Haparanda in Sweden. The only production facility owned by the company locates in Hollola where conveyor rollers are manufactured. Nepean Conveyors Oy's business encompasses the whole life cycle of the equipment, from engineering and fabrication of equipment to maintaining the equipment and delivering needed spare parts. Nepean Conveyors Oy biggest strengths are the know-how, flexibility and customer centric mentality. Figure 6 summarize the information regarding the business units at Nepean Conveyors Oy.

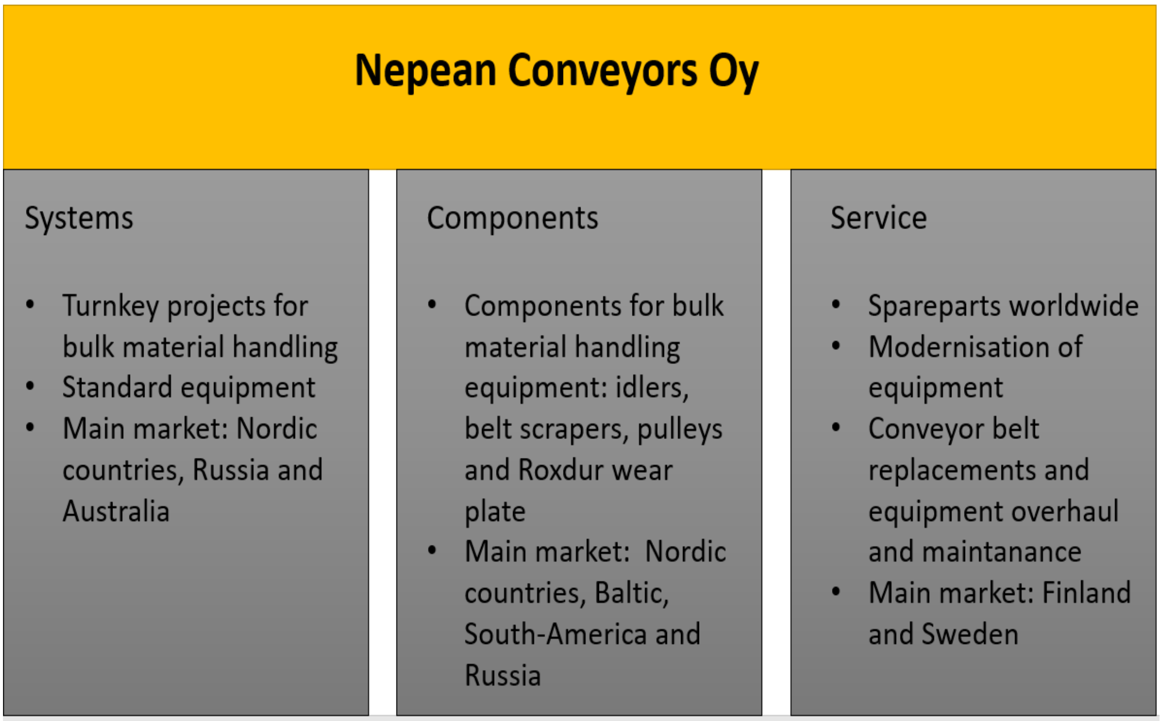

Figure 6. *Business units at Nepean Conveyors Oy.*

3.2 Project business (Systems)

The project business unit at Nepean Conveyors Oy is called Systems. Systems encompasses all type of projects from standard equipment to turnkey bulk material handling solutions. The product portfolio including ship loaders, belts conveyors, hoppers, reclaimers, stackers and apron feeders. The main business for Systems in recent years has been different type of belt conveyor projects for mines. The most important customers locate in the Northern Sweden.

The project business unit including five main functions: procurement, quality, engineering, project management and sales. The number of employees in 2021 working at Systems is 35 and in fiscal year 2020-2021 Systems generated a little bit over 11 million euros in revenue. Compare to other business units at Nepean Conveyors Oy, project business involves more risk and uncertainty due to complicated contractual relationships between Systems and its customers and temporary nature of projects. Furthermore, every project has its own documentation requirements, payment terms and contractual obligations.

Project size and complexity affect the structure of the project team, but normally a project team at least including a project manager and a project engineer. Every project has designated project manager who is responsible for the execution and management of the project. Furthermore, the project manager is responsible for informing and communicating with the key stakeholders of the project. A project engineer is responsible for technical aspects of the project such as compliance with the local safety regulations, functionality of the equipment and monitoring actual design and engineering work. Procurement, logistics, engineering and quality are supporting functions which are needed for a successful project execution.

Systems' structure is very flexible and much of the actual work in projects are outsourced. For example, the design of the equipment is partly carried out by key partners in Finland and the fabrication of the equipment is fully outsourced to key subcontractors in the Baltics. This make it possible quickly to adjust the cost structure to the level of workload, but when the markets are booming there is a risk of lack of fabrication and engineering capacity.

The projects have been divided in two categories: Standard Equipment and Material Handling Projects. Standard equipment requires less designing and engineering since the existing 3D models and drawings are modified to meet the customer requirements. Procurement in standard equipment projects is quite straightforward since suppliers are established and material requirement are normally known in early stage of the projects. Standard equipment projects are smaller in size and they have shorter lead times compare to material handling projects. Furthermore, standard equipment projects include less uncertainty than larger material handling projects and therefore major cost overruns are easier to avoid and less monitoring and control over the project is required.

Material handling projects are more complex since they are larger, technically more demanding and can include installation and commissioning. This complexity causes more uncertainty which requires more control over the project and monitoring the costs. Furthermore, more engineering and designing resources are needed, since this type of projects includes less standardized equipment, larger and more complex equipment and structures and more customer interfaces. Possible installation and commissioning require careful planning, since the site activities can cause major cost overruns and delays.

3.3 Project supply chain

Nepean Conveyor Oy's project supply chain is a typical engineer-to-order supply chain where every projects start with the design phase where equipment are design to meet the customer's specifications and requirements. The project business heavily relies on the supply chain, since most of the project related activities and work are outsourced.

Design work in projects is mostly carried out by external engineering offices in Finland. Furthermore, the fabrication of the equipment and steel structures are fully outsourced to key subcontractors in the Baltics. Systems doesn’t have its own site team and therefore, installation and commissioning of the equipment is also carried out by external workforce except site managers.

Since most of the project related activities and work is outsourced, the organizational structure of the Systems is very flexible and the number of employees and facilities can be kept relatively low. The downside of the outsourcing is to get needed production and engineering capacity during the market booms and the control of engineering and fabrication is more complicated than when these activities are done inhouse. Furthermore, there can be conflicting interest between the supply chain partners and Nepean Conveyors Oy. Especially Systems has struggled to keep the engineering and designing costs in the budget and this has directly affected project margins. Since these activities are outsourced, it may be the interest of engineering offices to get as much invoiced engineering and designing hours as possible. Therefore, monitoring of the progress of the designing work is utmost important.

Main components used in Systems equipment are conveyor belts, gearboxes, electric motors, pulleys, idlers, belts scrapers and belt scales. In addition, some switches, sensors and other type of electrical instruments are needed depends on the project. The main components are procured directly from manufacturers in Europe. Other components are mainly procured through distributors in Finland. Component suppliers locate in Europe and at the moment Systems doesn’t have any active supplier outside Europe. Even though the main components are procured from the well-established suppliers, there are project specific suppliers which are used seldom and only in particular type of projects. Most of the components suppliers in the ERP-system are seldomly used and relationships are transaction based. This has created a vast subcontractor base where average volume per a supplier is very low.

As mentioned earlier, fabrication is mainly carried out by the subcontractors in the Baltics. There are more than ten actively used subcontractors in the Baltics, but only three to four can be considered as key subcontractors. Other subcontractors are used as capacity backups if the key subcontractors don’t have enough capacity. Most of the subcontractors have been done business with Nepean Conveyors Oy for years, but the relationships are still mainly transactional and there haven’t been much effort to develop common information sharing practices. Language barrier is one obstacle to deeper and closer relationships, since language skills are significantly lower among the subcontractors, especially when it comes to English. Systems has one employee stationed in the Baltics who is responsible for monitoring the progress of the fabrication work and constantly visits subcontractors’ facilities.

Logistic companies are also crucial part of the supply chain in the project business, since there are a lot of material movement during the projects. Especially logistic companies are helpful when determining the most economical size of conveyor modules since oversized freights can caused significant extra costs and regulations vary country to country. Furthermore, it is important that materials arrived at the construction sites on time since loading capacity may be available only on certain days and small delays in shipments can cause significant delays or extra costs in site activities.

The core of project supply chain is formed by a handful of subcontractors, a couple of engineering offices, key component suppliers and one or two main logistic partners. Other suppliers vary more based on the project specification and the type of equipment needed. Bigger projects can include up to 100 suppliers, but most of these are low volume and project specific suppliers. These suppliers are loosely connected to the project supply chain and communication is minimal. Two main drivers that shape the supply chain are costs and lead times. Since projects has deadlines and delays can cause penalty fees and customer dissatisfaction, it is important to find suppliers who are able to match with the project schedule. Furthermore, ever increasing competition requires also to build a cost-efficient supply chain to win projects. Overall, the project supply chain constitutes only a handful of key suppliers and all other suppliers are loose connected to the supply chain and can be replaced if necessary.

4. CASE STUDY

4.1 Methodological choice

According to Sander et al. (2019, p. 130) “the research philosophy refers a system of beliefs and assumptions about the development of knowledge.” The research philosophy determines the perspective of how the research questions are understood, what methods are used to gather information and how the gathered information is interpreted (Sander et al. 2019, p. 130). Pragmatism is applicable research philosophy for business and management research projects since research starts with a problem, and try to contribute a practical solution. This means that pragmatism is more interested in outcomes than how researcher assumptions and beliefs affected the research’s outcomes. In this master’s thesis the research philosophy is pragmatism since the purpose of the research is to come up with key findings which can improve the case organization’s operations and practices. Pragmatism also allows to use both quantitative and qualitative methods in a research. (Saunders et al. 2019, p. 145 – 151)

The research method used in this master’s thesis is a case study where the phenomena are examined within its context through multiple sources of data (Baxter & Jack 2008). A case study can be single case or multiple-case study and the depth of the case study can be embedded or holistic. The holistic approach study the all the aspects of the case and embedded approach focusing on some particular part of the case (such as particular processes and a part of the company). (Baxter & Jack 2008) According to Yin (2018, p. 9) the case study is a suitable research method when the research study try to answer “how” and “why” type of questions. Voss et al. (2002) also emphasize the relevance of question “why” to the case study. Furthermore, when researcher has zero or a little influence on the behavior of those involved in the study or the phenomenon is fairly new, the case study is applicable research method (Yin et al. 2018, p.9). All the aforementioned aspects, and the complexity of phenomenon and its context dependency affected the decision to choose case study as a research method.

Typical case study explores organizations, individuals, processes, relationships or programs (Yin 2018, p. 14). In this master’s thesis the case study is embedded multi-case study where part of the project supply chain in the context of particular projects are studied and how information and materials flows are managed in that part of the project supply chain. The part of project supply chain that is examined constitutes of subcontractors responsible for steel structure fabrications, the case organization’s functions directly involved in information or material shipment processes and construction site involved in material storing and reception. In this research the number of cases was limited to three beforehand chosen projects. Selection of the case projects was done together with case organization's procurement manager and the head of project department. Main criteria for case projects were size, how current the project was and did the project involved sufficient amount of material and information flow between case company and its subcontractors and the construction site. Furthermore, one of the case projects involved installation at the construction site carried out by the company which made it more complex. Since some of the projects were really small and involved only small amount of materials, they weren't considered to make a case. Also more than one year old projects weren't qualified as a case since difficulties to recall the project details and emerged problems. The purpose of selecting set of cases is to identify major obstacles for efficient information and material flows in the case projects and try to come up with generalizable conclusions how digitalization can overcome those obstacles.

4.2 Data collection and analyzing methods

The conducted case study was a qualitative case study and therefore the primary data was acquired by carrying out interviews. The primary data can be defined as data collected for a particular purpose such as for a research project (Sanders et al. 2019, p.338) The interviewees included 3 subcontractors, 2 project managers involved in the case projects, procurement manager, site manager and the head of the project department. The interviews were chosen based on their knowledge or involvement of the case projects and interviews were semi-structured. In semi-structured interviews an interviewer starts with predetermined list of themes and key questions to guide the interviews (Sanders et al. 2019, p.413). This helps to control the course of the interviews and stay on the relevant subjects. However, semi-structured interviews leave space for open discussion and the flow of conversation determines the outcome of the interviews (Sanders et al. 2019, p.414).

Pragmatism enables to use different data collection methods and case study method often requires different range of methods which allows multiple facets of the phenomenon to be revealed and understood (Baxter & Jack 2008). In this thesis the interviews were the main source of data, but additional data was gathered from the case company's systems such as from ERP, intranet and project folders. Table 5 summarize the data gathering methods.

Table 5. *Data collection methods.*

Case Project A	
Interviewee	**Data collection method**
Project Manager	Semi-structured interview
Subcontractor A (Logistics Manager)	Semi-structured interview
Subcontractor A (Executive Director)	Semi-structured interview
Subcontractor B	Semi-structured interview
Procurement Manager	Semi-structured interview
The head of project department	Semi-structured interview
Case Project B	
Interviewee	**Data collection method**
Site Manager	Semi-structured interview
Subcontractor C	Semi-structured interview
Subcontractor B	Semi-structured interview
Procurement Manager	Semi-structured interview
The head of project department	Semi-structured interview
Case Project C	
Interviewee	**Data collection method**
Project Manager	Semi-structured interview
Subcontractor A (Logistics Manager)	Semi-structured interview
Subcontractor A (Executive Director)	Semi-structured interview
Procurement Manager	Semi-structured interview
The head of project department	Semi-structured interview

The interviews were mainly carried out through Microsoft Teams due to COVID-19 travelling restriction and organization's policy of working from home. The main topics and key questions were sent in advance to the interviewees to familiarize themselves with the topics to discuss about. The interviews were mainly carried out during June-August 2021, but holiday season caused some delays with the interviews. Additional information was acquired through unofficial conversation with the employees of the case organization, from case organization's ERP-systems and the project folders. ERP systems and project folders were mainly used to gather basic information about the case projects such as project size, project schedule, value of the project, how much materials was procured and shipped to the subcontractors and what kind of tools were used to managed the information and materials flows in the project supply chains. How the material flows and the information flows actually were managed and what kind of obstacles and difficulties the case project faced with communication, material shipments or document and information sharing were identified based on the interviews.

5. RESULTS

5.1 Subcontractors

All the subcontractors interviewed for the case study have been involved in multiple case company's projects. Subcontractor A has worked together with the case company over 17 years and can be considered the most important workshop for the case company. The case company is the biggest customer for subcontractor A and the relationship between these two companies can be considered as a partnership based on long-term mutual trust. In other words, relationship can be considered strategic where both parties looking mutual benefits from the relationship.

Subcontractor B has done business with the case company approximately two years. The case company isn't that big customer for subcontractor B and the relationship has been problematic recently due the quality issues and delays in deliveries. The relationship can be considered as transactional since there isn't much collaboration between the companies. Even though the case company doesn't considered subcontractor B as important supplier, they had important role in case project B due to lack of capacity in other subcontractors and competitive price they offered.

Subcontractor C is smaller workshop which has done business with the case company over two years. The case company is medium size customer for subcontractor B but there has been mutual trust between the companies. The lack of fabrication capacity has been major concern with subcontractor B and there has been some delays in fabrication due to insufficient capacity. However, subcontractor C is ideal workshop for smaller steel structure which doesn't require too much assembly work. Therefore the relationship with subcontractor C can be considered as collaborative where there as strong mutual trust between the companies and cooperation. Figure 7 presents the locations of the subcontractors in the supplier segmentation matrix.

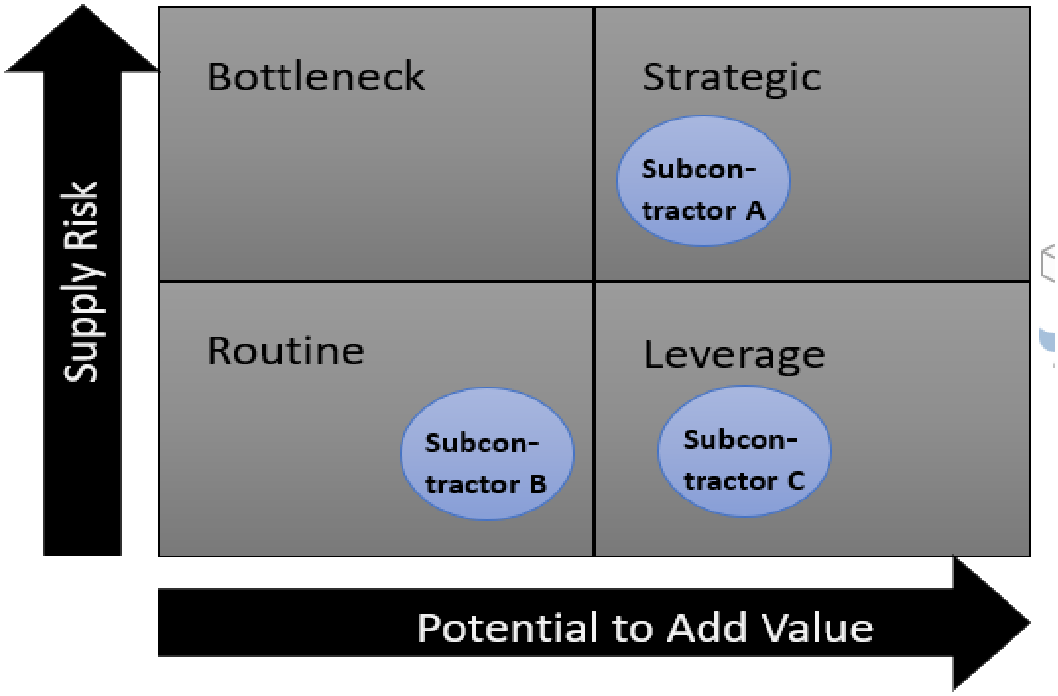

Figure 7. *Segmentation of the subcontractors.*

5.2 Case projects

All three case projects were chosen based on their size, relevance to the thesis and how recently the project has been completed. All the projects were completed at the time of interviews. As earlier mentioned the project can be categorized into two different category: Standard Equipment and Material Handling Projects. The case project A represent Standard Equipment and the case projects B and C Material Handling Projects.

The case project A was the smallest of the case projects by monetary value and project duration was the shortest one. The case project A represent typical standard equipment project where engineering and designing of equipment based on standardized structures and modules. Therefore less engineering and designing are needed than in turnkey projects where equipment are more complex and therefore, require a lot more engineering and designing. Even though this projects as categorized as a standard equipment, it is still engineering-to-order product where customer order and specification penetrate to design phase. Material requirements in standard equipment projects are more predictable since the equipment are based on standardized modules and structures that are modified based on the customer's requirements. This helps to plan and coordinate the materials flows in the supply chain since material requirements are mostly known in the early phase of the project. Overall, the project was delivered on time, but there were some issue with the customer's approval of general drawings. This caused some difficulties in the fabrication phase since the drawings were sent to the subcontractor in many batches and fabrication was on hold in many occasions.

The case project B was the longest by duration and the total monetary value of the project was the greatest. This project can be categorized as Material Handling Project based on the project size and complexity. The project started in June 2019 and was completed in November 2020. The duration of the project was long compares to other projects the case company have been delivered in recent years. The case project B was divided into two sub-projects based on the project deliverables. First sub-project was about the delivery of new belt conveyors to the customers including the installation of the belt conveyors. Another sub-project was about the modifying existing equipment and delivering additional steel structures needed for a new equipment layout. Both sub-projects were delivered simultaneously and the project teams was the same for both sub-projects. Therefore, these sub-projects can be bundled into one case project B.

The case project B was complex project due to the fact the end customer was building completely new coal ship loading facilities with the mix of existing equipment procured from elsewhere and new equipment delivered the case company. The modification of existing belt conveyors and fully upgraded multilevel transfer buildings required a lot of engineering and re-designing and therefore the materials requirements were clear only quite late in the project. Furthermore, the installation always brings another aspect to the material flow management since the installation phase is very vulnerable to any material delays or defects. The schedule of the case project B was revised quite a few time, mainly due to the customer and delays in the constructions of the foundation and other civil work. Furthermore, especially with one particular subcontractor there were issues with quality, missing materials, wrong item labelling and the assembly level of the equipment. These issues caused a lot of extra hours at the site and obviously caused a lot of extra costs to the case company. Overall, the case project B was very complex project due to the size of the project and amount of modifications and upgrades needed to fit the existing equipment to the new lay out.

The case project C is the most recent of the case projects and it started in July 2020 and was completed in June 2021. This project was a ship loader project to Taiwan and the project included engineering, automation and electrification of a ship loader and fabrication of key sub-assemblies of the ship loader. Some steel structures of the ship loader were fabricated locally in Taiwan due to the economy reasons. Since the case company hasn’t delivered ship loader in more than ten years, the lot of know how was lost and project team had a steep learn curve to overcome. The engineering and designing phase was much longer than expected and some of the material requirement were known only very late in the project. The case company struggled also to find suitable suppliers for the components since there weren't well established supplier network for this type of equipment. Therefore the lead times of some key components were hard to estimate and they arrived very late in the project. The packing of the materials for containers was also time consuming since there were 20 containers and four different suppliers who packed the materials into containers. The material packing at the end of the project is the step normally overlooked and underestimated how much time it requires. Overall, the project was delivered on time, but there were some issues with delayed materials and prolonged designing of the equipment. The table 6 below summarized the key figures of the case projects

***Table 6**. Case projects.*

Case Project A	
Project Duration	7 months
Project Scope	Engineering and fabrication of ten belt conveyors and upgrade of one existing belt conveyor.
Project Value	928 740 €
Purchased materials	782 857 €
Number of workshops	2
Project takeover	February 2021
Case Project B	
Project Duration	18 months
Project Scope	Engineering and fabrication of 6 new belt conveyors, 9 conveyor modifications, 3 fully upgraded multi-level transfer building, transfer chutes and divider gate systems along with other accessories.
Project Value	4 365 862 €
Purchased materials	1 504 592 €
Number of workshops	7
Project takeover	November 2020
Case Project C	
Project Duration	12 months
Project Scope	Engineering, automation and electrification of a ship loader and fabrication of a ship loader (except pylon, service platforms, portal and winch cover).
Project Value	3 081 640 €
Purchased materials	1 483 504 €
Number of workshops	10
Project takeover	June 2021

All the case projects had different end customers and the final locations. The case project B was very challenging project to manage due to the vast project scope, a lot of uncertainty at the beginning of project and site activities involved (installation of 5 belt conveyors). Other two projects were more defined at the beginning, but especially with the case project C there were difficulties to identify the amount of engineering work needed to design the ship loader. This was mainly because the case company hasn’t delivered ship loaders in ten years and a lot of the know-how was lost since the last ship loader project.

5.3 Material and Information flows

The case company’s material and information flow practices are studied based on the chosen case projects. Most of the information was gathered from the interviews but additional information was collected from the case company’s internal systems. Since project supply chain is quite often based on ETO products, most of the information shared along the supply chain is customer order or product related. The material requirements don’t based on the forecast, but instead the actual customer order triggers the material flow in the supply chain. Material and information flows are considered between the case company’s warehouse, subcontractors and the site. Direct material flows from the component suppliers to the subcontractors have been also taken into account.

5.3.1 Case project A

As mentioned earlier, the case project A was Standard Equipment project where the equipment design based on standardized modules and structures. Therefore, the design phase is more straightforward than in Material Handling projects and materials requirement are well known from the beginning of the project. The amount of materials procured by the case company was also moderate compare to many other project delivered recently. In this project there were only two workshops involved and the main subcontractor was subcontractor A. Other supplier was responsible for manufacturing idler brackets for the project which were deliver to subcontractor A for assembly. The fabrication of the conveyors lasted approximately 10 weeks and the conveyors were shipped to the end customer in 2 lots. The engineering phase was most time consuming since it lasted almost 5 months even though the project was categorized as Standard Equipment. However, this was mainly caused by customer’s slow approval of the general drawings which prevented further proceeding in the design.

In this project the case company procured the main steel materials for subcontractor A which was unusual since normally workshops procured the steel materials by themselves. According to the procurement manager this was mainly to make sure that steel materials will be on time because the project schedule was tight. Even though the design phase was quite long, the main component requirements were known in early stage and most of the materials arrived on time. However, there were some material delays which affected Subcontractor A production schedule and required some rescheduling. Subcontractor A also complained the lack of information about the delivery dates of the material acquired by the case company. This made it more difficult to accurately plan the production if there was no information when certain components and materials are about to arrive. Furthermore, there was no information which materials will be delivered directly to the subcontractor and which are shipped via case company's own warehouse. In the case project A, the only materials shipped directly from suppliers to subcontractor A were the conveyor belts, steel materials for conveyor frames, idler brackets. The conveyor belts were shipped directly from Italy to subcontractor A. The idler brackets were manufactured by subcontractor B and afterwards shipped to subcontractor A. Apparently all the materials were shipped to Subcontractor A where the final packing and loading into containers took place. Figure 8 presents the main material flows in the case project A.

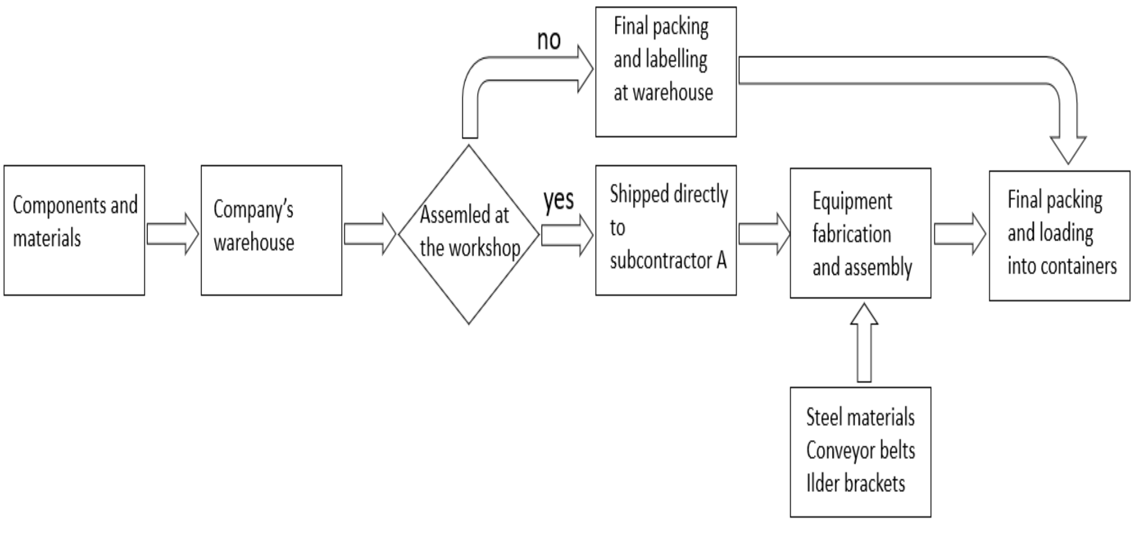

***Figure 8**. Material flows in case project A.*

The case company's warehouse was the first material consolidation point where materials and components were either shipped directly to Subcontractor A for fabrication and assembly or stored temporarily at the warehouse for final packing and labelling. The next material collection point was at Subcontractor A where all the materials and subassemblies were packed into container. The customer organized the pick-up of the containers to the harbor where the containers continue their journey to the final location.

During the project there were a lot of information exchange between the case company and Subcontractor A. There was also information exchange between the case company and Subcontractor B, but due to the smaller scope of supply communication was less frequent with Subcontractor B. Table 7 indicate how information was exchanged and what type of information was shared between the case company and the workshops (Subcontractor A and Subcontractor B).

Table 7. *Information exchange in the case project A.*

Type of data	**Communication Channel**	**Sender**
Purchase orders, ITP and surface treatment documents	By email	Case Company
Manufacturing drawings, BOM, Drawing list, Material List and Purchase parts list	By email and Sharepoint	Case Company
Progress report and photos on fabrication every week	By email	Subcontractor
Packing Instructions, list of parts (TAG list) and preliminary container loading lists	By email	Case Company
Completed loading and packing lists, photos about the packages and loaded containers	By email	Subcontractor

All the manufacturing drawings were send by email to Subcontractor B since the amount of drawings was very little. The main batches of drawings to Subcontractor A was shared via Sharepoint, but missing drawings ad revised drawings were send by email. The total amount of drawings batches to Subcontractor A was 25 which included revisions and missing drawings. One reason for many drawing batches was because the customer approved the general drawings conveyor by conveyor which delayed the design and equipment designs were completed in different time. This caused various difficulties for subcontractor A since the fabrication was continuous “start and stop”. The project manager was overall satisfied with the communication between the workshops and the case company, but the correctness of the completed packing lists from subcontractor A was an issue which cause some extra work. Furthermore, subcontractor B complained the amount of emails and revisions sent to them.

5.3.2 Case project B

The case project B was quite long project and therefore the fabrication and design phase overlapped for a long period of time. Materials were procured also in long period of time since the materials requirements were unknown in the early stage of the project and material requirements were revealed along the design progress. During the project the completion of fabrication was postponed approximately 2 months mainly delayed civil work at the construction site. The projects included 6 completely new belt conveyors and five of them was also installed at the site by the case company. The project scope included also modification of 9 belt conveyors and three transfer tower to fulfill the current safety requirements and fit the new equipment layout. Additional structures and components needed for modifications were supplied by the case company , but the installation of modified structures was organized and carried out by the customer. Overall, there were 7 workshops involved in the project and three workshops fabricated the main steel structures for the six belt conveyors. Other three fabricated primary streel structures for upgraded equipment and transfer towers and one workshop was entirely focused on idler bracket manufacturing. The main reason for such many workshops was that none of the workshops had capacity to fabricate all the required steel structures. The fabrication was going on during spring and summer in 2020 and normally that is the busiest time of the year for workshops in the Baltics. Subcontractor B manufactured two belt conveyors including the longest belt conveyor in the project and primary steels for modified transfer towers. Subcontractor C fabricated four chutes, additional steel structures for five modified belt conveyors and a hopper for stacker feed.

The workshops mainly procured steel materials for fabricated structures and all the components and other materials such as plastic wear plates, rubber materials and profile plates were procured by the case company. Case company’s warehouse was the main materials consolidation point were materials and components were divided in two groups: materials shipped directly to the construction site and materials shipped to workshops. Some materials procured by the case company were shipped directly to the workshops from suppliers. These materials included: fixing parts, profile plates, grates for service platforms, plastic wear plates, idler brackets and steel doors. Figure 9 below presents the material movement in the case project B.

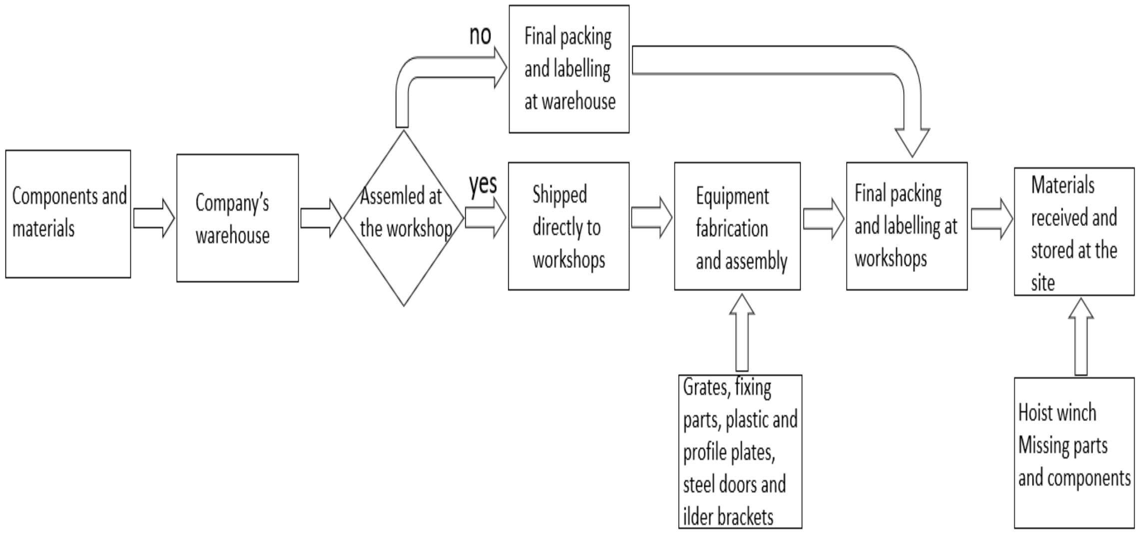

Figure 9. *Material flows in case project B.*

Ultimately all the materials were shipped to the construction site for installation, but the site received materials from three different sources: directly from suppliers, from case company's warehouse and from six subcontractors. Since there were many workshops involved, some materials had to repack based on workshops and material shipments required a lot of coordination. Some materials were first shipped to wrong workshops such as some profile plates. During the project there were some uncertainties which materials have been shipped to which workshops and have workshops received all the needed materials and components. Especially with fixing parts there were a lot of uncertainty and workshops needed to procure some of the fixing parts in order to proceed the fabrication of equipment.

The construction site was the last collection point of the materials and material shipments were schedule to support the progress of the installation. This means that the materials shipments were shipment on batches and each batches included materials for particular equipment. It was crucial that materials arrived on time at the site because any idle time at the site would have meant extra costs and delays at the installation. Furthermore, equipment needed for unloading the steel structures were rented so every hour costs money. Lastly, every difference between packing lists and actual delivery meant a lot of extra work to identify items and wrong labelling of items meant even more difficult identification process.

Information exchange happen between the case company and all the seven workshops involved in the project. How frequent the information exchange was, depended on the workshops' scope of supply. Subcontractor B supplied steel structures for two new belt conveyors and their scope was the biggest in the project. Subcontractor C had smaller scope of supply which included many chutes between modified belt conveyors and the hopper. The site manager wasn't directly contact with the workshops but was informed about the expected completion dates of the steel structures and pre-assembly level at the workshops. Table 8 gathered the main type of data and information shared in the project between the case company, workshops and the site manager.

Table 8. *Information sharing in the case project B.*

Type of data	**Communication Channel**	**Sender**
Purchase Order, ITP and Surface treatment document	By email	Case Company
Manufacturing drawings, BOM, Drawing list, Material List and Purchase parts list	By email and Sharepoint	Case Company
Progress report and photos on fabrication every week	By email	Subcontractor
Packing Instructions and part lists (TAG list)	By email	Case Company
Completed loading and packing lists, photos about the packages and pallets	By email	Subcontractor
Installation drawings and manuals for electric equipment	By email	Case Company
Loading and unloading schedules	By email	Case Company
Missing materials and material defects	By email	Site Manager

The manufacturing drawings to subcontractor B was mainly sent by email and in total there were 35 drawing batches sent to the subcontractor B but 25 drawing batches included less than 10 manufacturing drawings. The amount of manufacturing drawing batches sent to subcontractor C was 24, but 15 drawing batches included less than 10 manufacturing drawings. The manufacturing drawings constitute the main type of data shared between the case company and the workshops, but packing lists and loading schedules were important information for the site manager to identify materials and prepare enough unloading capacity at the site. There were some issues with the item labelling and packing lists included items which weren't actual delivered at all. Also subcontractor B didn't supplied all the goods which were in their scope so the site manager had to source them locally. This caused delays in the installation work and ultimately resulted significant extra costs for the case company.

5.3.3 Case project C

Subcontractor A fabricated primary steel structures for the ship loader excluding a pylon, service platforms and a portal which were part of customer's scope. There were were exceptionally many workshops involved in the project due to the fact that a ship loader requires more specialized subcontractors than conventional belt conveyor project. Most of the components such bearings, belt cleaners, electric components, pulleys and rollers were first shipped from suppliers to the warehouse, but there were many materials which were shipped directly from suppliers to subcontractors. Electric components were mainly forwarded to the subcontractor responsible for electrification and control of the ship loader. Materials and mechanical components were mainly shipped to subcontractor A, but there were materials which were shipped to also other subcontractors in Estonia. The amount of components and materials procured by the case company was significant and it was arduous job to organize all the transportation to different workshops and keep the records which materials are shipped where and when. The case company's ERP system only support the material shipment to one location and couldn't be used to tract the material movement to various places. For example polycarbonate sheets were first delivered from supplier to one subcontractor and then to subcontractor A for the assembly. This type of material movements are only recorded to spreadsheets. Figure 10 illustrates the main material movements in the case project C.

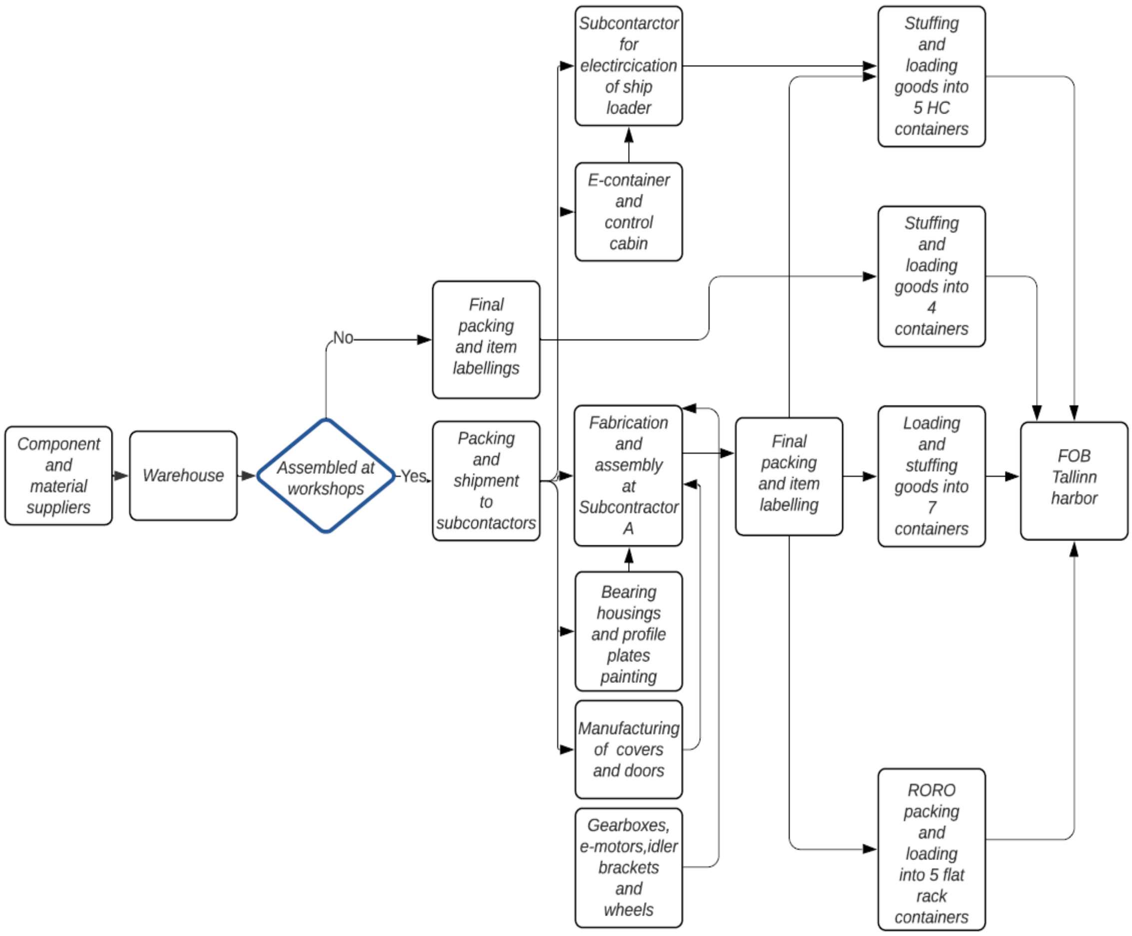

***Figure 10**. Material flows in the case project C.*

The number of subcontractors involved, and different kind of container packing and loading requirements made it very challenging to coordinate and track the materials flows in the project. There were a lot of material delays in the project which tightened even more already tight fabrication and assembly schedules. Due to the material delays, direct shipments by courier to subcontractors were organized which meant some additional logistics costs. Final packing, item labelling and container loading was time consuming task since there were a lot of small items need be marked and some steel structures needed special kind of container packing. The number of container packing companies was four which meant a lot of material flow coordination that right materials were shipped to right container packing company.

During the project there were some information exchange between all the subcontractors and the case company, but the main focus in the case company was the information exchange with subcontractor A and the subcontractor for electrification and ship loader control. These two subcontractors had significant role in the successful delivery of the project. Furthermore, there were significant amount of information exchanged between the case company and container packing subcontractors. Table 9 summarize the type of information shared during the project between the case company and the subcontractors.

Table 9. *information exchange in the case project C.*

Type of data	Communication Channel	Sender
Purchase Order, ITP and Surface treatment document	By email	Case Company
Manufacturing drawings ,BOM, Drawing list, Material List and Purchase parts list	By email and Sharepoint	Case Company
Progress report and photos on fabrication every week	By email	Subcontractor
Packing Instructions and part lists (TAG list)	By email	Case Company
Completed loading and packing lists, photos about the packages, pallets and loaded containers	By email	Subcontractor
Information on arrival of materials and components to subcontractors	By email	Subcontractor
Container ID numbers and Seal numbers	By email	Subcontractor
Container packing and loading instructions and loading sketches	By email	Case Company

Progress reports were mainly received from subcontractor A since the scope of supply for many other subcontractors was very small. Manufacturing drawings were sent to all subcontractors, but the amount of drawings for almost all the subcontractors were very small. However, subcontractor A received in total 41 batches of drawings, but 20 batches included less than 10 manufacturing drawings. Subcontractor A received in total many hundreds of drawings which was quite time consuming to manually check especially when some drawings were revised many times.

5.4 Current level of digitalization in management of information and materials flows

Based on the case study interviews and additional information gathered from the case company's ERP and other systems, the current level of digitalization in material and information flow management is quite low. Purchased orders and a lot of manufacturing drawings are sent to subcontractors by emails. Furthermore, materials flows to subcontractors are mainly managed by using the excel sheet called "Purchase parts list". This list contains information about material quantities, required delivery dates, who is the supplier, what is the purchase order and where materials will be shipped from suppliers. The shipments from subcontractors to the site are managed by using loading lists. Loading lists are made for every shipments and they including information about item description, which subassembly items belongs to, quantity of items, number of packages in the shipment, package type, weigh and dimensions. For example in the case project B there were 65 loading lists in total. Figure 11 shown typical loading list in the case project C.

CONTAINER No: R3995-001

R3995
Taiwan Shiploader
PORTAL_1

DATE	18.6.2021
TRUCK NO.	
TRAILER NO.	
Container no.	MAEU4166168
Seel no.	ML-EE0158962
NET WEIGHT	22823
GROSS WEIGHT	23670
VOLUME (m^3)	50,06

Package type
P Pallet | CR CRate
CA CArton | U Unpacked
B Bundle | O Other

Transportation Type: CONTAINER 40' OT
Delivery Terms: xxx
Country of Origin: ESTONIA
Country of Export: ESTONIA
Country of Destination: TAIWAN

Collection Address:
STAKO DILER

Supplier:
Nepean Conveyors Oy
Keskikankaantie 19
15860 HOLLOLA, Finland
Contact: Mrs. Pirjo Koponen
Tel +358 40 7583710
Mail: pirjo.koponen@roxon.fi

Delivery address:

Consignee:

PACKAGE NO.	ROW NO.	ITEM No.		DENOMINATION		DESCRIPTION	PARENT	POS	QTY	PACKAGE TYPE	STACKABLE	STORAGE	DIMENSION (cm)			VOLUME	WEIGHT (kg)	
		Customer	Nepean	(EN)									L	W	H	(m^3)	NET	GROS
101	1		RL3996 H1102887 / Portal	Bogie Assembly Corner B		H1102478 w/o Guard Plates (H1102020 Pos 6-10, H1102484 Pos 5-9) & EEQ (H1105692 Pos 1-7, H1106222 Pos 5)	H1102887	2	1	O	N	Cold Indoor	605	200	200	24,20	11333	11400
	2		RL3996 H1106238 / Maint.	Bogie Installation Equipment		H1105913	H1106238	1	1									
103	1		RL3996 H1102887 / Portal	Bogie Assembly Corner C		H1105725 w/o Guard Plates (H1102020 Pos 6-10, H1105726 Pos 6-10) & EEQ (H1105874 Pos 1-7 , H1106222 Pos 5)	H1102887	3	1	O	N	Cold Indoor	605	200	200	24,20	10680	11400
	2		RL3996 H1106238 / Maint.	Bogie Installation Equipment		H1105913	H1106238	1	1									
102	1		RL3996 H1102887 / Portal	Guard Plate		H1105586	H1105714	5	1	P	N	Cold Indoor	223	80	50	0,89	170	200
	2		RL3996 H1102887 / Portal	Guard Plate		H1105587	H1105714	6	1									
	3		RL3996 H1102887 / Portal	Guard Plate		H1103108	H1105714	7	1									

Figure 11. *Loading list.*

ERP system is mainly used to purchase items and inbound logistics. Inbound logistics in this context means material flows from suppliers can be trace to one location whether it is the construction site, the warehouse or subcontractors. When materials are shipped directly to the site or to subcontractors they need to inform the case company's procurement department about the arrived materials. Once the procurement department has received information about arrived materials, receipt of materials can be created on ERP system. Information on arrived materials are normally informed by emails and many times the procurement department had to request the information about the specific items and their status. Furthermore, the case company doesn't have any tools to automatically track which purchase orders are delayed. Purchase order tracking is done manually by checking the confirmed delivery dates on ERP and compare it with the current status of the purchase orders.

Email is the dominant communication channel for external and internal communication. Almost all the documents are shared by emails and emails include a lot of additional information about agreed assembly level of equipment at subcontractors, issues with fabrication and clarifications of scope of supply. Therefore, there are a lot of information that is only in someone's inbox and not shared with others involved in the matter. This creates siloed information since information is only available for certain person or group. For example, if certain assembly level of equipment is agreed with the subcontractor without knowledge of exact arrival dates of components, it can lead to delayed fabrication or lower than desired assembly level of equipment which means more installation work at the site.

Microsoft SharePoint is mainly used to share manufacturing drawings with subcontractors if there are multiple drawings shared at the same time. Microsoft Teams is used to communicate internally or externally, but it is seldomly used to communicate with subcontractors. Furthermore, the case company has used a freeware programming language called AutoIT which can automate repeated tasks on Microsoft's graphical user interface. However, according to informal discussion with the case company's IT Systems Analyst, AutoIT is mainly used to automate new software installation and the finance used it to identify purchase orders where some critical information is missing. Nevertheless, AutoIT can be also used to collect data from one source and copy it to another source, comparing different source of information if it in standard form and automate data entry to ERP.

5.5 Main issues identified with information sharing and materials flows

The case study interviews revealed some themes that repeated in many interviews. Since the case projects where different in size, scope, complexity and duration not all the issues in the case projects were the same. Bigger projects obviously involves more subcontractors and materials which complicates the material flow management and information sharing. Furthermore, the practices and tools convenient in smaller size projects can turned out to be less sufficient in bigger projects. Therefore, not all arose issues in the case project are identical. However, there were some dominant themes identified based on the interview. Table 10 presents main issues arose by the subcontractors in the case projects.

Table 10. *Main issues identified by subcontractors.*

Issues Identified	Case project A	Case project B	Case project C
Delayed Materials	X	X	X
Insufficient information about materials procured by the case company	X	X	X
The scope of supply unclear	X		X
Drawing revisions caused extra work	X	X	X
Difficult to identify materials shipped directly from suppliers	X		X
Too many emails regarding assembly or revised drawings		X	X

Some themes repeated in all the case projects such as insufficient information about materials procured by the case company. Both interviewees from subcontractor A and the interviewee from subcontractor C emphasize this theme. Furthermore, especially subcontractor A hoped for better understanding of scope of supply from early on since both case projects they were involved there was some unclarity with the scope. Also a lot of revised drawings and huge amount of sent drawings in short time caused some difficulties especially for subcontractor A and subcontractor B. Subcontractor B and C have difficulties to report weekly progress. Lastly, subcontractor A mentioned that materials procured by the case company were significantly delayed which cause a lot of problem with production planning and resource allocation. Especially, the case project C had a lot of materials which were late and the workload in fabrication accumulated in the end of the fabrication phase.

Obviously interviewees in the case company had different perspectives than subcontractors, but there were same issues arose in these interviews also. Almost all the interviewees acknowledged that the case company didn't provide enough information about the materials procured by the case company. Another issue arose in the case projects B and C was the difficulty of monitoring fabrication progress. Table 11 presents the main issues arose by the interviewees in the case company.

Table 11. *Main issues arose by the case company.*

Issues Identified	Case project A	Case project B	Case project C
Insufficient information about materials procured by the case company	X	X	X
Incorrect packing list information	X	X	
Delayed materials		X	X
Difficult to monitor progress of fabrication		X	X
Missing materials and material identification at site		X	
Delayed Fabrication		X	
Coordination of material flows		X	X

Interviewees in the case company identified especially delayed materials, difficult to monitor progress of fabrication and insufficient information about materials procured by the case company as main themes to focusing on. Furthermore, especially in the case project B there were problems with delayed fabrication of equipment. Delayed fabrication caused approximately one month delay in installation work since materials weren't at the site as originally planned. Furthermore, there were also quality issues in case project B with subcontractor B which caused significant extra work at the site. The coordination of materials flows in case project B and C was time consuming since there were a lot of materials shipped to different subcontractors and all these logistics activities were recorder in the purchase parts list mentioned earlier. The project manager in case project C mentioned that purchase parts list wasn't up-to date and there were a lot of confusion whether materials have been shipped to the subcontractors or not. Missing materials at the site and material identification was only mentioned in case project B because two other case projects didn't included site activities. Material identification is almost impossible if the labels aren't correct on items. According to the site manager at case project B material identification was time consuming if some items aren't marked or the packing lists aren't correct.

Based on the interviews almost all the interviewees identify problems with sufficient information about the materials procured by the case company. However, it was a little surprised to the procurement manager and the project managers how important it is for subcontractors to have up-to-date information when and what materials are expected to arrive at subcontractor's facilities. It is difficult to allocate resources and plan production and assembly work if there is no information about the materials needed in production or assembly. Especially subcontractor A emphasis the importance of sufficient information sharing about the materials procured by the case company. Difficulties to identify materials shipped directly from suppliers are directly linked to insufficient information about materials. Many cases materials just showed up without any notification in advance. Furthermore, some materials were difficult to identify because material labels were missing, items description was different than in drawings or there were no information about the project or equipment items belong to.

6. ANALYZING RESULTS

6.1 Categorizing identified issues

Identified issues can be divided in the same categories presented in the literature review. Most the issues identified in the interviews are linked to material flow issues or information sharing related issues. Figure 11 summarizes the findings both in the literature review and issues identified based on the interviews.

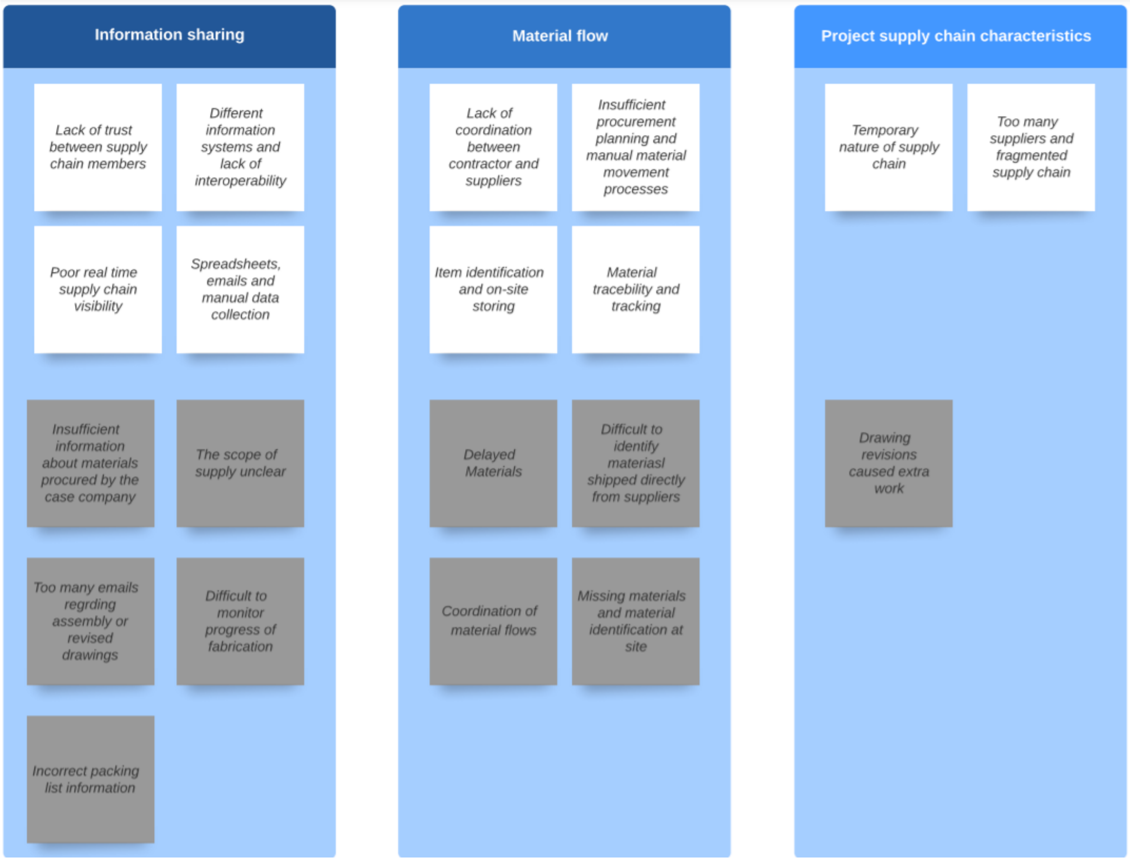

Figure 11. *Summary of identified issues in the literature review and from the interviews.*

The reason why drawing revisions can be considered as the project supply chain related issue, is because drawing revisions are mainly result of overlapping fabrication and design phases. Project schedules are many times very tight and therefore the fabrication cannot wait until the design is completed. The overlap of engineering and project execution is one of the characteristics of the project supply chain and it is very difficult to design equipment completely and then commence manufacturing if the project schedule doesn't allow enough time for that.

Material flow related issues involved delayed materials, coordination of material flows, missing items at the site and material tracing and tracking. When compared material flow issues identified based on the interviews and the findings in the literature review, they are almost exactly the same. Delayed materials are directly linked to insufficient procurement planning and manual material movement processes. According to the procurement manager in the case company, most of the material delays in the case projects were due to late procurement of items or insufficient purchase order tracking. Furthermore, the dates when materials are needed are not always known when placing purchase orders. Material identification can be linked to material tracing and tracking. When material can be trace in real-time there is no difficulties to identify the items once arrived. Coordination of materials flows in the supply chain can be seen common theme both in the literature and empirical data.

Identified issues related to information sharing vary a little bit more from the literature review than the identified material flow issues. Difficult to monitor progress of fabrication can be linked to poor real-time supply chain visibility. All the subcontractors involved in the fabrication of steel structure should report weekly progress by using excel template. However, the problem is to get the weekly reports from subcontractors and how reliable the weekly reports are. Fabrication delays can be caused by lack of visibility what happens at subcontractor’s facilities and has subcontractor progressed as planned. Especially newer subcontractors require a lot of monitoring of progress since there are lack of trust between the parties. Furthermore, too many emails can cause delays in response with can be lead further delays in the projects. Based on the interviews, the main communication channel was the email and some subcontractors found it troublesome to keep track all the emails and documents sent via email. Incorrect packing lists were identified an issue by the case company since variation between actual delivery and the packing lists cause a lot of extra work at the site.

The insufficient information about the materials procured by the case company is related to lack of interoperability and different information systems. As mentioned earlier all the information regarding what have been procured and what are the expected delivery dates can be found in the excel sheet called “Purchase parts list”. However, this information is not shared with subcontractors and therefore they don’t have any idea when the materials are expected to arrive.

6.2 How digitalization can enhance information sharing and seamless material flow in project supply chain

Based on the interviews, data collection from the systems and informal discussions, it is clear that the current level of digitalization in the project supply chain isn't high. Most of the information is gathered to different spreadsheets such as the purchase parts list, packing lists and tag lists. When information is gathered to spreadsheets it is very time consuming to keep the information up-to-date and information is very scattered.

Identified issues in the project supply chain were divided in three different categories. Only identified issue which was related to project supply chain characteristics was drawing revisions which is the result of overlapping of manufacturing and engineering phases. Obviously, amount of revisions can be reduced, but it is difficult to overcome this issue by exploiting digital technology since many revised drawings originate from the customer requests.

In the literature review, digital technologies were identified to overcome or reduce obstacles for efficient information sharing and material flows in the project supply chain. Table 12 presents the identified issues and what digital technologies are suitable for solving the issues based on the literature review.

Table 12. *Digital technologies and application to enhance the efficiency of the project supply chain.*

CATEGORY	ISSUES	DIGITAL TECHNOLOGY	BENEFITS
INFORMATION SHARING	Insufficient information about materials procured by the case company	Cloud computing (SaaS)	Real-time information and remote access
	Too many emails regarding assembly or revised drawings	Cloud computing (SaaS)	Information sharing via cloud is transparent and remove space from email Inbox
	Difficult to monitor progress of fabrication	Cloud computing (SaaS)	Progress reports in cloud server where designated people have access to it
	Incorrect packing list information	Cloud computing (SaaS) & QR code	Automated data entry by using QR codes and information is saved to cloud based server

MATERIAL FLOW	Delayed materials	RPA (software bot)	Automated order tracking from ERP system
	Missing materials and material identification at site	Cloud computing (SaaS), QR code & FRID tag	QR code or FRID tag contains material information saved in cloud server and logistics transactions can be automated
	Coordination of material flows	RPA (software bot)	Automated data collection from ERP

Table 15 shows clearly that the most prominent applications and technologies for the case company's project supply chains are: Cloud computing (SaaS), QR code and RPA. FRID technology could be otherwise suitable for material identification and item tracking, but it has significantly higher investment costs than QR code-based systems. FRID system could be suitable for real-time tracking of very expensive shipment or if the exact arrival time of trucks are needed for example to reserve unloading capacity. QR code could be also suitable for automatic data entries in the packing list to avoid incorrect information. This would only need a smartphone to scan QR codes and a cloud-based software where the transactions are recorded and can be monitored.

Cloud based-systems offer more available and up-to-date information. Furthermore, remote access to a cloud server is very simple and effortless since internet access is practically all what is needed. Therefore, sharing information via cloud has many advantage over the email. Creating a common cloud portal with the subcontractors where all the information is shared provides easy information access, up-to-date information and free space in the email inbox. In the common cloud portal information regarding delivery dates of materials and material delays can be shared with subcontractors and progress reports can be shared via cloud instead of emails. This will lead better visibility of supply chain, since the subcontractors can better anticipate when the materials will arrive and adjust their resources accordingly. Furthermore, the progress reports are more easily accessible when they are not in one person's email inbox, but instead shared via cloud portal.

In addition, there are countless of possibilities with current IT software which the case company has. Microsoft Teams can be used to manage the whole project and material flow processes can be easily to integrate to this platform. Microsoft Power Automate is very usual tool to automatically send emails or save attachment in the email to a certain folder. Furthermore, AutoIT together with Python scripts can be used to automatic data entry and information retrieve from the systems. Since the case company uses multiple excel sheets to handle the logistics and material flows in the project supply chain, the information is very scattered and there is too little overviews of transactions and events. RPA technologies make it possible to easily gather information from different sources and summarize the information. Better overview of transactions and events ultimately helps to make right decisions which lead to more efficient project supply chain.

7. DISCUSSION AND CONCLUSION

7.1 Answering the research questions

In the beginning of this masters' thesis the following research question was defined.

- *How digitalization can enhance the efficiency of the project supply chain.*

This research question was answered by answering two sub-questions defined in the beginning of the thesis. The first sub-question was defined as following.

- W*hat are main obstacles for sufficient information sharing and seamless material flows in the project supply chain*

Material flows have huge impact on project supply chain's performance since material costs make up significant percentages of total goods capital project costs. Secondly, multiples studies indicate that incorrect materials and material delays make up to 50 percent of project delays and cost overruns. Furthermore, supply chain integration and prompt information sharing can lead to better flexibility and agility in the supply chain which ultimately improves the performance of whole project supply chain.

For above mentioned reasons material flows and information sharing have huge impact on the efficiency of whole project supply chain. Multiple obstacles for seamless material flows and sufficient information sharing in the project supply chain was identified. Main obstacles for seamless material flows were almost the same both in case study and in the literature review. These obstacles are: *lack of material flow coordination between supply chain members, insufficient procurement planning and manual material flow processes and lack of material traceability and identification*.

There was a little bit more variation between identified obstacles for sufficient information sharing in the project supply chain between the case study and the literature review. Based on the literature review one of the obstacles of sufficient information sharing was lack of trust between supply chain members. However, in the interviews there was no mention about the lack of trust. On the contrary, especially all the subcontractors stated their good relationship with the case company. Even though the lack of trust didn't come up in the interviews, it is obvious that the lack of trust prevents sufficient information sharing in the project supply chain. Poor supply chain visibility results from lack of access to real-time information which hinders free flow of information throughout the project supply chain. Therefore, obstacles for sufficient information sharing in the project supply chains are: *lack of trust between supply chain members, different information systems* *and lack of interoperability*, *poor supply chain visibility and emails and manual data collection*.

The second sub-question was defined as following.

- *What digital technologies and applications support sufficient information sharing and seamless material flow in the project supply chain*

Based on the case study and the literature review, the most prominent technologies and applications for the project supply chain are: *robotic process automation (RPA), QR codes and Cloud computing (SaaS)*. RPA has multiple possibilities to automate whole processes or part of the processes. Whenever there are repeated tasks, there are possibilities for RPA. RPA technology can be used to collect data automatically or for automated data entry. Furthermore, RPA technologies can be used collect data from multiple sources and summarize the data. Some examples of RPA applications are: AutoIT and Microsoft Power Automate. QR codes are suitable for material tracing and item identification. It has many advantages such as low investment costs and no need for special equipment or technologies. There are multiple free QR code generators. Lastly, cloud computing (SaaS) offers better information accessibility compare to organization's own systems or servers. Cloud computing can be integrated with multiple technologies such as QR code, FRDI technology or RPA.

7.2 Theoretical and research implications

The current scientific literature discussing the digitalization of the project supply chain isn't very comprehensive and even the term "project supply chain" is mentioned only in very few academic publications. Therefore, it was necessary to define the project supply chain by aligning supply chain management theories with the project context. Most of the publications covering the digitalization of the supply chain are focused on the process-based industries where demand is more predictable and inventories play huge role balancing demand and supply. Especially there isn't many scientific publications focusing on the information and material flows and how digitalization can enhance seamless flow of materials and information throughout the project supply chain.

This study was conducted as a case study where primary data was gathered from semi-structured interviews, from the case company's systems and informal discussions with the case company's employees. Three subcontractors from the Baltics were also involved in the interviews. The language barrier between the interviewer and the interviewees may have affected the results since foreign language spoke in the interviews may have hindered interviewees to say everything they wanted to say. This research was also limited to information and materials flows between the case company, subcontractors and the site. Therefore, the results of this research can only apply in the small part of the project supply chain in the context of the case study.

7.3 Conclusion

Digitalization is one of the major trends affecting both societies and businesses all over the world. There are multiple opportunities of supply chain digitalization that includes increased access to information, optimized logistics between companies in the supply chain, better supply chain visibility and transparency through real time information access and control, efficient inventory management, increased end-to end integration and connectivity in the supply chain.

Many project businesses are suffering from fragmented and loosely connected supply chains where visibility throughout the whole supply chain is poor. Furthermore, material flow coordination in the project supply chain is challenging especially when the design and manufacturing phases overlap since material requirements aren't known precisely when manufacturing commences and flexibility is required to adapt the material changes. Spreadsheets and manual data collection are still very relevant material flow management tools in many project supply chains. Furthermore, most of the information in many project supply chains are shared via emails which can be ignored for very long period of time causing delays in the project. Main benefits of digitalization for project supply chain are more connected supply chain where information is shared promptly and supply chain visibility increases.

Main digital technologies to support prompt information sharing, better supply chain visibility and efficiency in the project supply chains are: robotic process automation (RPA), Cloud computing (SaaS), QR codes and FRID technology. RPA can collect information from various sources and automate data entry into systems. Furthermore, it can automatically send emails, collect data from emails and save attachment of emails to a certain folder. All these functionalities support more efficient information sharing. Cloud computing enable better information access and can partly replace emails as a communication channel. QR codes and FRID technologies are suitable for material identification and tracking and therefore increase the visibility of the supply chain.

Even though digitalization can greatly benefit a project supply chain efficiency and visibility, employee's resistance to changes have be taken into account. As mentioned earlier, digitalization has disruptive impact on transactional activities in the supply chain due to machine learning and automation. This will mean some vacancies in the organization will vanished because manual work decrease. Furthermore, funds are limitation to further digitalization since all investment on new technologies requires time and money. Sometimes the benefits of new technologies aren't that easily converted to exact figures which makes the decision making more difficult.

7.4 Future research

This research offers good insight of what issues are related to the project supply chain's material and information flows and how digitalization can enhance information and material flows in the project supply chain. One of the themes that arose from the interviews was difficulties to monitor progress of fabrication at subcontractors. Currently, the progress was monitored by using spreadsheets and some additional photos. However, progress reports are excel sheets which don't give accurate data about the progress and it is hard to check if the given data is correct. One of the biggest benefits of digitalization is better real-time visibility in the supply chain. Therefore, one possible future research topic could be how digitalization can enhance the visibility of outsourced manufacturing and what kind digital technologies support real-time remote manufacturing progress monitoring.

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