CHALMERS
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Logistics Performance Measurement System for Construction Supply Chains

A Case Study at a Large Swedish Construction Company

Master's thesis in Supply Chain Management

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Technology Management and Economics
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

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Abstract

Logistics management in a construction supply chain can be seen as a key competitive factor due to the importance of perfect deliveries towards construction sites. The increased importance of logistics in construction supply chains explains why the evaluation of logistics effectiveness and efficiency is gaining increased attention. Logistics performance management is the key to quantifying the current state and improvement potentials within logistics. In order to ensure that the logistics of a supply chain is performing well, it is crucial that the company measures different aspects of the logistics flow of the supply chain. As stated by Sink and Tuttle (1989): *"You cannot manage if you cannot measure. If you do not measure you do not know what you have achieved and where you are headed".*

This master thesis aims to investigate and give suggestions on how to measure the logistics performance of a construction supply chain. This can also be seen in the research questions of this report, which are *"How should a logistics performance measurement system for a construction supply chain be designed?"* and *"Which KPIs should be included in a logistics performance measurement system of a construction supply chain"?*. This master thesis is based on a case study at a large Swedish construction company. Thereby the key performance indicators (KPIs) related to the logistic processes in a construction supply chain were examined.

One of the main findings of this master thesis is the creation of a conceptual framework, which focused on the design of a logistics performance measurement system (PMS). The framework takes company, industry, and supply chain characteristics into consideration, and designs the logistics PMS around those findings. The conceptual framework made it possible to identify four supply chain dimensions that should be covered when designing a logistics PMS for construction supply chains: supply chain reliability, efficiency, responsiveness, and sustainability. Furthermore, six strategic KPIs were identified that should help construction supply chains to measure their logistics performance. These KPIs were: perfect order fulfillment, fill rate, transportation cost per ton-km, backlog, customer ordering lead time, and CO2 emission per ton-km.

Keywords: construction supply chain, construction industry, performance measurement system (PMS), logistics performance measurement system, key performance indicator (KPI).

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It has been an interesting and challenging project, where we have been able to apply the knowledge that we acquired during our education. Furthermore, we have also acquired new knowledge, experience and acquaintances.

We would like to thank all the employees at Bygg AB who have been involved and contributed to the result. However, we would like to address a special gratitude to:

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We hope that our master thesis will give Bygg AB and construction industry in general, insight and inspiration into how to design a logistic performance measurement system and what KPIs to include in it.

Andreas Zetterberg & Jonas Minges, Gothenburg, June 2017

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1 Introduction

This chapter gives a short introduction into the background of this thesis and the case company that will be studied. Also, a summarized description of the problems that this thesis will focus on will be provided, as well as an introduction to a number of research questions. Furthermore, the aim of the thesis is stated in order to describe the content of the project and to explain what the objective is. Finally, a section about limitations will illustrate what the report focuses on, and which areas will not be covered.

1.1 Background

Construction companies face an increase in competition and have experienced for several years that the customers today require lower cost, higher quality, shorter execution duration's, and more reliable schedules (Azambuja and O'Brien, 2009). At the same time, the combination of the characteristics of a supply chain and the construction industry, is usually described as both fragmented and temporary (Thunberg and Persson, 2014). This is explained by the project based environment, making every supply chain setup unique. However, this has also led to arms-length relationships, lack of coordination and poor communication between participants (Roberti et al., 2013). Logistics management in a construction supply chain is thus seen as a key competitive factor due to the importance of perfect deliveries towards construction sites. The aim of logistics management can be said to be more efficient and to increase the cost efficiency in the whole supply chain. If materials are not delivered to the construction site in the correct amounts, at the correct time and without any deficiencies, the construction site's production process will likely be affected due to potential delays and consequently the quality to customers (Thunberg and Persson, 2014).

With the increased importance of logistics in construction, the evaluation of logistics effectiveness and efficiency is gaining increased attention. Logistics performance management is the key to quantifying the current state and improvement potentials within logistics. A PMS, consisting of several KPIs, is seen as a key for creating transparency and a trigger for improvement ideas (Dörnhöfer et al., 2016). In the context of the construction industry, managing the communication and relationship with subcontractors will lead to less fragmented supply chains, greater control and focus on quality (Karim et al., 2006).

The design of a proper logistics PMS requires consideration of several aspects. Ensuring that the PMS is in line with the company objectives and strategy will enhance strategy fulfillment by lower level management (Dörnhöfer et al., 2016). The selection of KPIs and the setting of targets of these measures should be seen as concrete formulations of the firm' strategic targets (Lohman et al., 2004). A holistic view is important to consider when looking at material flows in construction industry (Thunberg and Persson, 2014). As companies across several industries move towards a more integrated operations management function across the supply chain, it becomes necessary to measure the logistics performance of the different parts of the supply chain on various dimensions. Furthermore, in order to understand causes of deviations of actual performance from targeted performance, each KPI should be able to be drilled down to different measures and levels of detail (Lohman et al., 2004).

1.2 Case company - Inköp AB

This master thesis is based on a case company, which will be anonymous due to existing compliance agreements. Hence, from here on out the case company will be referred to as "Inköp AB" and can be described as an import company within a large Swedish construction company. The primarily objective for "Inköp AB" is to act as an purchasing organization which sources certain product segments from low cost countries within Europe. The large actor which owns Inköp AB will also be anonymous, and is therefore referred to as "Bygg AB" in this report.

The case company, Inköp AB, in this study was founded in 1995 after an initiative from "Central Purchasing" at one of the largest construction companies in Sweden, Bygg AB. When Bygg AB company's structure in Sweden was divided into regional companies, there was a need for an entity that could handle the year-end bonuses in an efficient way, as well as a company that could represent Bygg AB in Sweden at joint procurement initiatives. Such close-to operational tasks should and could not be handled under the construction company, hence Inköp AB was created.

Today, Inköp AB is a strategic tool which is used in order to enable international procurement in a more efficient manner than what project based procurement can achieve. The company is part of Bygg AB's Nordic procurement function. It is considered as an import company which mainly sources from low-cost countries. Bygg AB intend to use it in selected areas where they need leverage to put pressure on the domestic market, promote technical development in a certain direction, achieve economies of scale or where they see other added values gained compared with the regular sourcing process.

1.2.1 Function and service characteristics

The function of Inköp AB is to mainly be world class purchasing department which help projects to source certain product categories for a lower price through import from low cost countries within Europe. The company works as an interface between the construction projects and the suppliers. Instead of the projects handling all communication with different suppliers, Inköp AB can approach the supplier market with one interface, setup of routines and focal points of contacts. Hence, there is a possibility for bundling volumes and administration costs for procurement can be kept at a low level.

Inköp AB has a local presence in one of the countries in which they source from, where the material is bought in local currency to domestic prices. Thus, they can also run efficient work with audits of sustainability, safety, quality. The projects can focus on their task since they need little administration in communication, follow-up and risk management among others.

Since Inköp AB is a focal point for the projects they are also responsible for setting up the transportation of the sourced material to the project site. The logistics for the products that Inköp AB are purchasing, is outsourced and handled by a large 3PL which operates internationally. The logistics is an important part in the Inköp AB model.

1.2.2 Case problem description

Inköp AB has experienced problems in their logistics performance towards construction sites, where the efficiency, reliability and safety has been insufficient. Late deliveries towards the construction site often stalls the entire construction project, which can lead to operational and expensive delays for Bygg AB. The reason for this is that Bygg AB is Inköp AB's customer. Therefore, it is of highest importance that Inköp AB can deliver in the right time, quantity and quality. Furthermore, some of the conducted transports have not been economically justifiable. This could be an indication of low fill rate in the transports, operational to unnecessary high costs. Another problem regards the deliveries of Inköp AB goods, where some customers have experienced safety issues when unloading goods. The safety performance is something that directly affects the brands of both Inköp AB and Bygg AB. The reason for the perceived safety issues, are believed to mainly origin from poor loading, which is executed by the truck driver and the material supplier .

The transportation of goods is currently outsourced to a large 3PL, although Inköp AB is still responsible for planning and consolidating the orders. Thus, it needs to be ensured that the agreements with the 3PL and the material suppliers contain appropriate information and clearly states who is responsible for what. Accordingly, Inköp AB need to have well developed agreements which include the right performance indicators in order to control and improve their performance.

1.3 Aim and research questions

The aim of this master thesis is to investigate and give suggestions how to measure the logistics performance of a construction supply chain. This will be done by conducting a case study at Inköp AB, and thereby examining the KPIs related to the logistics processes in a construction supply chain. Finding appropriate KPIs should help improve or design a logistics PMS of a supply chain. Dörnhöfer et al. (2016) define logistics performance management as the key to quantifying the current state and improvement potentials within logistics. The research questions for this master thesis are expressed as follows:

RQ1. How should a logistics performance measurement system for a construction supply chain be designed?

- This refers to the process of developing a performance measurement system and how the process should be structured.

RQ2. Which KPIs should be included in a logistics performance measurement system of a construction supply chain?

- Refers to a set of KPIs that should measure how well the logistics in construction supply chains performs.

1.4 Limitations

The thesis focuses on the supply chain processes between Inköp ABs supplier and the construction site. Therefore the KPIs that are being studied in this report will be related only to the logistics processes of Inköp ABs supply chain. Furthermore, the focus of this master thesis is only on Inköp AB's largest product group in terms of turnover, reinforcement.

A supply chain mapping is conducted by using the supply chain operations reference (SCOR) model as a framework. The SCOR model is not used in order to improve the internal processes on a detailed level, instead it only seeks to visualize the current state and give control to the management.

In order to create a new logistics PMS, the most suitable KPIs from existing theory are "cherry picked", thereby not limiting the findings of this report to only one type of source or specific framework. "Cherry picked" means that research in the literature was made, were the best parts were identified and applied. Instead PMS are thoroughly examined in order to identify the best way of measuring and controlling a construction supply chain under complexity.

The findings of this report are well motivated, and give the board of Inköp AB valuable suggestions to how the output can be used. However, this master thesis will not implement these, leaving to the case company to decide upon what and how much of the findings that will be chosen to adapt.

2 Theoretical framework

This chapter starts by explaining the construction industry and its characteristics. Secondly, supply chain management is described, where the concepts of supply chain performance and strategy is explained, as well as providing some theory regarding the uncertainty framework. The next section is about performance measurement, which aims to explain how to design a PMS, and how it can be used in order to achieve increased control in a company. In the same section a template for how to design KPIs is described, there stating general KPI characteristics. Thereafter, logistics performance management in supply chain context is presented.

2.1 Construction industry

This section will give a short introduction about the construction industry and its characteristics, thereby giving important input to the analysis in regard to how the construction industry differentiates itself from other industries.

The construction industry is a project based environment, where the industry is characterized by having the production site being built up around the building that is going to be produced (Persson et al., 2009). This is also stated by Baccarini (1996) and Ekeskär and Rudberg (2016), who also describe the construction industry as highly complex. According to Fernández-Solís (2008) the construction industry has 3 specific peculiarities:

1. Each project is unique
2. Each project is carried out on a production site, which means it will be exposed to weather and specific site conditions
3. Each project has a new customer and thereby a different team

Fernández-Solís (2008) furthermore discusses that there is a gap between the construction industry and the traditional manufacturing industries. The gap refers to the fact that the efficiency in those manufacturing industries is far superior compared to the construction industry, which according to Fernández-Solís (2008) can be attributed to the lack of theory in the construction industry. The construction industry does not behave like a normal industry, and is too different for being able to directly translating past behaviour of specific industries toward itself. Due to the differences in scale and domains, the construction industry can not easily adapt theories from manufacturing companies (Fernández-Solís, 2008).

Azambuja and O'Brien (2009) also describe the product demand to be less uncertain in the construction industry (compared to manufacturing industries), due to that the amount of material normally is known some time in advance. However, there are also a number of issues regarding the production variability. Here Azambuja and O'Brien (2009) state that the project site is dependent on labor availability and productivity, the use of certain tools, and how it is also being affected by the open environment (weather). Furthermore, the project sites have a lack of standardization and tolerance management, and often have problems with no space availability on site. Also, the material and trade flows can be seen as more complex, thereby leading to higher variability (Azambuja and O'Brien, 2009).

According to Ortiz et al. (2009), the construction industry has during the past proven to be a big part of the social and economic sustainability in our society, where they employ millions of people and are a huge part of the economic sustainability of various countries. Sustainability most often is associated with three main areas; social, economic, and environmental sustainability. However, the construction industry has its problems with the environmental sustainability, where the sector is among others responsible for high-energy consumption, solid waste generation, global greenhouse gas emissions, and much more. Since there is a recognized problem in environmental sustainability, governments and environmental agencies are suggested to apply certain construction codes and environmental policies in order to improve the sustainability in construction. Ortiz et al. (2009) claim that for this reason, the construction industry should proactively create environmental, social, and economic indicators which promotes sustainable construction practices. This connects to one of the research questions of this report: *"Which KPIs should be included in a logistics PMS of a construction supply chain?"*, where the suggestion about proactively working towards sustainability should be kept in mind.

2.2 Supply Chain Management

In order to design a PMS and select its KPIs, it is extremely important to consider the context and strategy of the company that is used. Therefore this chapter will be about supply chain management and strategy which give the right tools to choose the appropriate strategy a company should use. Hence, the appropriate KPIs can be selected which is aligned with the supply chain strategy. Furthermore, since this thesis focus on construction industry there is also a section about construction supply chain management.

Supply chain management is a concept that was developed in the 1980s for managing the relationship between supply chain members in order to cope with the increased globalization of manufacturing (Houlihan, 1985). As Thunberg and Persson (2014) mention, supply chain management emphasizes the possibility of viewing companies within the supply chain as a collective entity rather than independent units. Ballou et al. (2000) further describe supply chain management as a term that refers to all the activities that are associated with the transformation and flow of goods and services, which also includes the attendant information flows, from the sources of raw materials to the end users. The word "management" there refers to the integration of all the activities, both internal and external to the company. Lee (2002) describes supply chain management as one of the major areas for companies to achieve the possibility of gaining a competitive edge. Probably the most accepted definition of supply chain management was given by the Global Supply Chain Forum, which defines it as:

"Supply Chain Management is the integration of key business processes from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders" (Lambert and Cooper, 2000).

2.2.1 Supply Chain Strategy

According to Chopra and Meindl (2016), a supply chain's competitive strategy can be defined by the set of customer needs which the company is trying to satisfy through the products or services that the company is offering. Furthermore, the supply chain strategy is considered to affect several factors. The supply chain strategy determines the nature of procurement of raw materials, the logistics of the material flow in the supply chain and the manufacturing of the product or providing of the service. Moreover, it also affects the distribution to the customer, as well as the possible follow-up services and a specification regarding if the processes will be performed in-house or if they should be outsourced (Chopra and Meindl, 2016).

There are several indicators that can signal if a supply chain is out of control. Such indicators could for example be a company that faces pressure of excessive inventory, has degraded its customer service, has escalating costs and declining profits or has a poor return on assets (Lee, 2002). In order to counter these challenges and to be prepared for new markets and technologies, a company should prepare and adapt their supply chain strategy to their context, since one-size-fits-all mentality will fail. A similar claim is also made by Chopra and Meindl (2016) who state the importance of aligning the company's context and objectives to the supply chain strategy. Lee (2002) furthermore states that the right supply chain strategy to use for companies is determined by a number of different factors. First, the strategy should be tailored towards the supply chain, and the specific needs of the customers. Second, the products with stable demand and reliable supply should be managed differently than a source of supply with unpredictable demand.

2.2.2 The uncertainty framework

In order to know which supply chain strategy to choose, Fisher (1997) developed a framework where the main objective was to help managers understand the nature of the demand for the products which the company supplies. This should help the company to understand how the supply chain should be structured and what strategy to use in order to satisfy the demand of the products. The first step for an effective supply chain strategy is to understand the nature of the demand for the products, which the author divides in two main categories: Functional products and Innovative products. Functional products are products which aims to satisfy basic needs of the customers, with stable and predictable demand. However, Fisher (1997) claims that due to the stability, there is a big competition which leads to lower profit margins. Examples of functional products is e.g. a stapler, which can be bought at different retail stores across the country. The other category mentioned by Fisher (1997) is innovative products, which among others can be characterized by more variety than functional products. Innovative products have the advantage that they often have a very high profit margin. However, innovative products are also considered to be volatile, with an unpredictable demand and short life cycles. Due to the differences between functional and innovative products, Fisher (1997) strongly recommends companies to use supply chains that fit each context. In Table 2.1 a comparison between functional and innovative products is presented.

Functional products	**Innovative products**
Low demand uncertainties	High demand uncertainty
More predictable demand	Difficult to forecast
Stable demand	Variable demand
Long product life cycle	Short selling season
Low inventory cost	High inventory cost
Low profit margins	High profit margins
Low product variety	High product variety
Higher volumes per SKU	Low volumes per SKU
Low stockout cost	High stockout cost
Low obsolence	High obsolence

Table 2.1: Demand Characteristics (Lee, 2002).

The framework by Fisher (1997) could be considered to be inconclusive, since it does not take into account other factors than the demand uncertainty for a product. For this reason, Lee (2002) extended the framework and added an extra dimension when selecting strategy: the supply uncertainty. The framework which Lee (2002) developed is called the uncertainty framework, where the initial description of Fisher (1997) is used, which claims that the supply chain strategy should be selected depending on the characterization of their products. According to Lee (2002), the uncertainties revolving around the supply side of the product are equally important as the demand, which led to the development of the earlier work done by Fisher (1997).

The supply uncertainty is divided into two groups, stable- and evolving supply. Stable supply processes refers to a situation where the manufacturing processes and the underlying technology of the supply base is well established. Evolving supply processes are on the other hand referring to manufacturing processes and underlying technology which are still in an early development phase and where the supplier base is still limited in both size and experience (Lee, 2002). The differences between these two groups can also be seen in Table 2.2.

Stable Supply Process	**Evolving Supply Process**
Less breakdowns	Vulnerable to breakdowns
Stable and higher yields	Variable and lower yields
Less quality problems	Potential quality problems
More supply sources	Limited supply sources
Reliable suppliers	Unreliable suppliers
Less process changes	More process changes
Less capacity constraint	Potential capacity constrained
Easier to changeover	Difficult to changeover
Flexible	Inflexible
Dependable lead time	Variable lead time

Table 2.2: Supply Characteristics (Lee, 2002).

As mentioned before, Lee (2002) added supply uncertainty to the work conducted by Fisher (1997). Lee (2002) continued by creating a table which combined both demand- and supply uncertainty, which is displayed in figure 2.1, where one axis shows supply uncertainty, and the other axis presents demand uncertainty. It is more challenging for a company to operate its supply chain in the right and bottom column of the uncertainty framework (referring to high demand and supply uncertainty). According to Lee (2002) a company should therefore aim to reduce both types of uncertainties, meaning that a company should ideally try to move into the top left box. Doing so should improve the supply chain performance. In order to move away from the right or bottom column in the uncertainty framework, Lee (2002) suggest the use of uncertainty reduction strategies. One of these strategies is the reduction of demand uncertainty. This could be done by for example achieve an increase in information sharing or closer collaboration in the supply chain. Another strategy that is suggested is to reduce the supply uncertainty, which according to Lee (2002) and Skjott-Larsen (2007) can be achieved by e.g. changing sourcing strategy from single to dual sourcing, involving suppliers in new product development, or by sharing safety stocks or critical items with the suppliers.

According to Fisher (1997) and Skjott-Larsen (2007), a supply chain can be either an efficient supply chain, or a responsive supply chain. Skjott-Larsen (2007) claims that the supply chains for innovative products should be responsive, while functional products should use an efficient supply chain. This is true, however Lee (2002) concludes that there are four appropriate strategies to choose between, depending on the supply- and the demand characteristics of a company's products. In the uncertainty framework, all four boxes (possible scenarios) are connected to different strategies, as can be seen in figure 2.1. The four strategies that are mentioned in the uncertainty framework will here be more thoroughly explained:

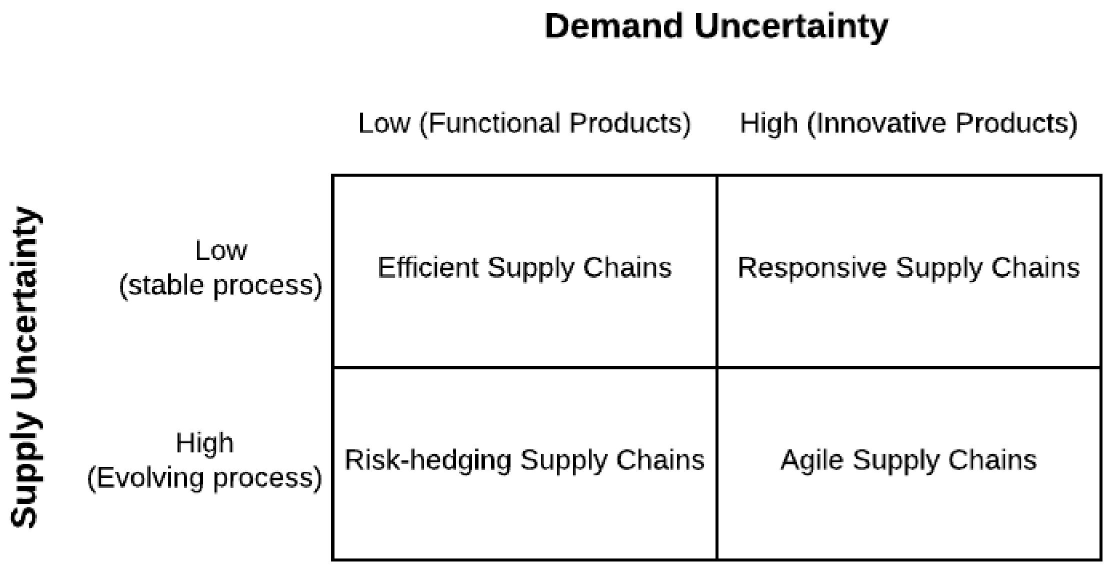


Figure 2.1: Strategies in the Uncertainty Framework (Lee, 2002)

- **Efficient Supply Chains** - These supply chains are constantly aiming for creating a cost efficient structure, mainly by eliminating non-value adding activities pursuing economies of scale and by deploying optimization techniques in order to achieve a high capacity utilization in production and distribution. Furthermore, efficient supply chains look to establish information linkages in order to achieve the best possible transmission of information across the organization (Lee, 2002).
- **Risk-hedging Supply Chains** - This strategy is well suited for supply chains that aims to share resources so that the risks in supply disruption is also being shared. Lee (2002) explains that this kind of risk-hedging strategy decreases the risk of supply disruptions by sourcing from more than one supply source. Other ways of reducing supply risk is to increase the safety stock of key components, and to keep this stock together with other companies to share the risk with each other (Lee, 2002). As can be seen in figure 2.1, the risk-hedging strategy is best suited for supply chains with high supply uncertainty (evolving process) and low demand uncertainty (functional products).
- **Responsive Supply Chains** - Having a responsive supply chain refers to the aim to be flexible and ready when having to fulfill customer needs. This strategy is proposed for innovative products with a stable process (high demand uncertainty and low supply uncertainty). According to Lee (2002), build to-order processes and mass customization are means to use in order for the company to meet requirements from the customer. Lee (2002) claims that the key to mass customization is the order accuracy, meaning accurate specification of customer requirements).
- **Agile Supply Chains** - The most challenging position for a supply chain is according to Lee (2002) when both the demand- and the supply uncertainty is high. In that case the supply chain needs to be agile, meaning there is an

aim to being responsive and flexible in regard to customers. At the same time risks of shortages or disruptions in the supply should be hedged by pooling inventory or by using capacity resources. Lee (2002) states that these kind of agile supply chains need to be responsive towards the demands of the customers and at the same time minimize the risks of supply disruptions.

This uncertainty framework should also be adapted to Inköp ABs context in the analysis of this report. By analyzing the supply- and demand uncertainty, this framework gives a suggestion to what type of strategy to use. Doing so and finding a suggestion for which strategy to use should facilitate the answer to the research question *"How should a logistics performance measurement system for a construction supply chain be designed?"*.

2.2.3 Construction Supply Chain Management

The combination of the characteristics of a supply chain and the construction industry, can usually be described as both fragmented and temporary (Thunberg and Persson, 2014). Azambuja and O'Brien (2009) have compared supply chains from the construction industry to supply chains from manufacturing industries, and highlights the differences. The structure of the construction industry can be described as highly fragmented, with low barriers of entry, transient locations, low interdependence and is predominantly used in local markets. This view is supported by Ekeskär and Rudberg (2016) who state that since construction work is carried out in temporary organizations, their supply chains are also temporary. Roberti et al. (2013) mention that a number of different studies have noticed the fragmented nature of the industry, relationships by arms-length, the lack of coordination and the poor communication between participants. The fragmented nature could according Roberti et al. (2013) be the reason why the industry is suffering from poor performance, e.g. by time and schedule overruns, quality defects, and poor safety performances, leading to increasing production costs.

The construction companies face an increase in competition and have experienced that the customers today require lower cost, higher quality, shorter execution duration's, and more reliable schedules. Azambuja and O'Brien (2009) also claim that the construction supply chain thereby can be seen as both complex and ineffective. The complexity partly origins from the fact that 60-80 % of the gross work done in construction projects involves the buying of materials and services from suppliers and subcontractors. In other words, these supply chain actors have a huge impact on the performance of the construction projects (Ekeskär and Rudberg, 2016). According Thunberg and Persson (2014) construction industry performance could benefit from greater attention to supply chain management. If materials are not delivered to the construction site in the correct amounts, at the correct times and without any deficiencies, the construction site's production process will likely be affected due to potential delays and quality issues (Jang et al., 2003). Ekeskär and Rudberg (2016) conclude that many of the issues have their origin upstream in the supply chain but their effects propagate to the construction site. Thunberg and Persson (2014) also highlight the poor delivery service in the construction industry, indicating that less than 40 % of deliveries are delivered in full (right, amount, right time and location, damage free and right documentation). A more holistic view is important to consider when looking at material flows. Flaws in the sourcing process, from material suppliers to construction site affect the production process in many ways and consequently the quality to customers (Thunberg and Persson, 2014).

According to Pan et al. (2010), implementing supply chain management in construction could lead to improved time performance, cost control and quality. Furthermore, the construction industry is considered to have some issues in the information flow, where Azambuja and O'Brien (2009) claim that the information flow needs to be recreated several times between trades. The authors go on and describe how the construction industry appears to be slow and describes a lack of sharing across firms, and also that there is a lack of IT tools for support of the supply chain. The relationship with the subcontractors is of utmost importance since much of the work is performed by them. Managing the communication and relationship with subcontractors will lead to less fragmented supply chains, greater control and focus on quality (Karim et al., 2006).

2.3 Performance measurement

The research questions of this master thesis are *"How should a logistics performance measurement system for a construction supply chain be designed?"* and *"Which KPIs should be included in a logistics performance measurement system of a construction supply chain?"*. Since a main part of this report is to design a PMS, the following section will be a guidance of how PMS are created and designed, will present different measurement systems, and will describe what characteristics a KPI should have.

The importance of measuring performance in any business is widely accepted. Neely et al. (2000), define performance measurement as: *"As the process of quantifying the efficiency and effectiveness of action"*, and performance measure as a *"metric used to quantify the efficiency and/or effectiveness of an action"*. The terminology differs between authors where Marr (2012) uses the terms performance indicator or KPI as a substitute to performance measure. Both Cox et al. (2003) and Lohman et al. (2004) further state that the use of performance measures is a way for the management to evaluate employee performance of some sort of task or operation. It compares the actual and the estimated performance in terms of effectiveness, efficiency, and quality in terms of both workmanship and product. This can also be seen in a quote about performance measures, made by Sink and Tuttle (1989):

"You cannot manage if you cannot measure. If you do not measure you do not know what you have achieved and where you are headed"

Thunberg and Persson (2014) claim that the use of KPIs can be used for assessing how well a company is achieving its strategic goals. This is also confirmed by Lohman et al. (2004) who highlight the importance to connect the KPIs to the firm's strategy.

The selection of KPIs and the setting of targets of these measures should be seen as concrete formulations of the firms strategic targets. If there is a gap between the actual level of the performance and the desired goal, appropriate actions should be initiated based on the knowledge gathered by the performance indicator (Lohman et al., 2004).

2.3.1 KPI characteristics

When selecting appropriate KPIs for supplier evaluation, it is important to choose KPIs that possess the right attributes. According to Gordon (2008), a good measurement for supplier performance should include a number of different characteristics. First, it should be meaningful and valuable, meaning that the measures should be directly connected to the organization's strategies and goals, and be measuring the most important activities of the supplier in regard to both the customer requirement and their own business success factors. Furthermore, the measures should be balanced, referring to that they should contain several types of measures, both internal processes and external outcomes. Gordon (2008) continues and states that a good measure for supplier performance should be linked and practical, meaning that the measure should be connected to the customer firm and that the capturing and retrieving of data should be quite easy and affordable. Another aspect stated by Gordon (2008) is that the measures should be comparable, credible and timely. Finally, the measurement should be pretty simple but at the same time robust, meaning that it is well proven. Gordon (2008) moreover states that one should not measure too many things, instead focusing on measuring so many that it is still possible to manage them.

Strategic and Operational KPIs

KPIs can be either strategic or operational. According to Marr (2015), the strategic KPIs are indicators that monitor the current state in comparison to where the company wants to be in the future. Operational KPIs on the other hand are measuring on a daily basis, and try to achieve real-time measurements. Operational KPIs thereby allow the company to adjust faults, and improve directly, before a full-blown escalation has appeared. Strategic KPIs are on the contrary only measured on a longer time horizon, there to visualize where the company currently is on its way towards its strategic objectives (Marr, 2015).

2.3.2 Performance measurement system

In the upcoming section, the concept regarding PMS will be thoroughly explained, which is closely connected to the research question and aim of this master thesis. A general PMS has an important role in operations and in business strategy implementation. For operations management it provides requisite information for monitoring, controlling, evaluation and feedback functions (Olsen et al., 2007). In addition, Tonchia and Quagini (2010) present a bullet list of seven components describing the purpose of a PMS:

- Translation and verification of corporate strategic plans and support for intervention/improvement programs.
- Comparison with the performance of its best competitors
- Control/monitoring of operational activities
- Coordination of activities
- Evaluation of human resources
- Involvement and motivation of human resources
- Individual and organizational learning ("learning-by measure" and "learning by error")

Neely et al. (2000) and Tonchia and Quagini (2010) describe that the PMS can be viewed at three different levels or layers; elements, architecture and interfaces. The individual performance measures are the first level in a PMS and is labeled as elements. According Lohman et al. (2004), a PMS includes the set of metrics used to quantify the efficiency and effectiveness of actions, as well as the procedures associated with the data collection, as those described in section 2.3.

The second level, the so called architecture layer, is divided between three architectural features. The first feature, vertical, has the purpose of dividing the indicators in accordance to where they fit in the organization where Tonchia and Quagini (2010) differ between strategic, tactical or operational. The second feature has the purpose to define what indicators that are suitable for the different organizational units and how these are shared and compared with different functions. The last feature defines what indicators are actually able to measure and monitor organizational processes (Tonchia and Quagini, 2010). In addition, Neely et al. (2000) mention that this level should also include how the indicators relate to each other and how well they cover business and improvement objectives.

According Neely et al. (2000), the integration of a PMS into the organization is a part of the interface layer and the environment surrounding the PMS is taken into consideration. It is important that the PMS is aligned with the business goal and strategy. Tonchia and Quagini (2010) furthermore state that the PMS should be put in a broader context with other systems within a company such as the enterprise resource planning (ERP) system etc.

2.3.3 Design of performance measurement system

The following section describes the design of PMS. This should be critical to the outcome of this thesis, since one of the research questions is strongly connected to this: *How should a logistics PMS for a construction supply chain be designed?*.

The design of a PMS is mainly about identifying key objectives and designing measures (Bourne et al., 2000). According Lohman et al. (2004), this step involves a clear definition of the firms mission statement and to identity the firm's strategic objectives, using the mission statement as a guide. Furthermore, it is important to develop an understanding of each functional area's role in achieving the various strategic objectives (Lohman et al., 2004). This is also highlighted by Andersen and Fagerhaug (2002) who mention the importance to understand and map the current business structures and processes. Hence, the design of the PMS will consider the organization, its competitive position, the environment it exists in and its business. The next step is to develop the elements of the PMS, the performance indicators which is considered to be the most critical aspect. According to Andersen and Fagerhaug (2002), the purpose of this step is to develop the PMS with an appropriate number of relevant and precise performance indicators. Senior Lecturer Ola Hultkrantz (Lecture on performance measurement, 28th September 2015) recommend to carefully choose one's KPIs since people can only retain 3 to 7 concepts in short-term memory. Thus, it is recommended to apply the 5 +/-2 rule.

Marr (2015) have developed a ten-step performance indicator decision framework in order to decide on the right KPIs.

1. **Linking KPIs to Strategic Objectives** - The strategic objectives of the business should lay as a foundation when developing new KPIs. Marr (2015) mention that when KPIs are tightly linked to objectives, they provide relevant information that can be used to monitor progress and show the right direction.
2. **Identifying the Unanswered Questions** - A KPI should answer important and relevant questions that are currently unanswered. Here it is important to identify the right KPQs (Marr, 2015).
3. **Isolating the Decisions to Take** - The identification of the KPQs could give a number of KPIs to use. Although, Marr (2015) suggest to reduce this list by isolate the decisions you could take as a result of the KPI information.
4. **Checking for Existing Data and Methods** - Existing data and data collection methods should be investigated so that time isn't wasted on designing something that is already existing (Marr, 2015). This is also something that is mentioned by Andersen and Fagerhaug (2002) who emphasize the importance of early address how and from where data is supposed to be collected.
5. **Collecting Meaningful Data in Time** - The quality of the data, the right format and that it is possible to collect the data at required frequency should be assured (Marr, 2015).
6. **Assessing the Usefulness to Answering the Question** - The developed KPIs needs to be assured that they can be used to make better informed decisions. If no decisions can be made as a result of the data, then the KPI is worthless and should either be left or be replaced by an alternative (Marr, 2015).
7. **Creating Awareness of Cheating** - The possibility of people manipulating the KPIs needs to be evaluated. Since KPIs have targets, it can affect how data is collected and reported in favour for a higher value (Marr, 2015).
8. **Are the costs and efforts justified?** - According to Marr (2015) if the KPI is expensive, time-consuming or if there is a problem in justifying it then one should go back to step four and consider if the same information can be

retrieved more efficiently.
9. **Collecting the Data** - If the KPI has reached this stage then data should be collected in order to use the KPI (Marr, 2015).

2.3.4 Framework for KPIs

According to Andersen and Fagerhaug (2002), designing reporting and performance data presentation formats is the next step in the developing phase of the PMS. In order to eradicate the ambiguity, ambivalence, and inconsistency which often is the issue with data collection and KPI reporting, Marr (2015) has developed a KPI design template, see figure 2.2. It contains of several elements, where the first part addresses the basics of each KPI and help to put it in context. The second part covers the more technical aspects of the data collection. The third part review how good is the indicator (Marr, 2015). Lohman et al. (2004) have developed a similar template for performance indicators reporting which supports and can be compared with the template from Marr (2015).

The basic of each KPI should cover five different elements. In order to understand the relevance of the KPI, Marr (2015) and Lohman et al. (2004) highlight the importance of clearly stating which strategic objective the KPI relates to. Marr (2015) furthermore states that it might be appropriate to also define the person(s) which are responsible for the management and the delivery of the strategic objective. The second element cover the audience and access rights. Here the primary audience of the KPI is defined. Basically this clarifies who will see the data and who will have access to it. When implementing KPIs, it is important that they give information and answers to what is needed to know. Therefore KPQs are needed, which captures what exactly managers need to know and is therefor perceived as the third element. Marr (2015) explains that the key performance questions (KPQ) are supposed to shift focus towards what is actually important to know, thereby being a guidance when selecting the appropriate KPIs to use. This element can be compared with Lohman et al. (2004) who mention this as the scope of the KPI. How the KPI should be used should be clearly communicated so that everyone who uses the KPI understand how it contributes and what it measures (Marr, 2015). According to Marr (2015), this is especially important if a new set of KPIs are introduced. Lastly, the framework should also include the factors that influence the performance, i.e. organizational units, events, etc (Lohman et al., 2004).

The technical aspects of the data collection should cover eleven elements:

- **Indicator name** - The indicator name should clearly state what the indicator is about. Therefore, the name should be able to be discussed collectively without causing any misunderstanding (Marr, 2015; Lohman et al., 2004).
- **Data collection method** - The data collection method should be identified and described for each KPI. This could include surveys, questionnaires, interviews, focus groups and collection of archival data. Here it is important to keep the strategic objective and KPQ in mind (Marr, 2015).

- **Targets and performance threshold** - A target should be defined for each metric as well as performance thresholds where performance levels are judged to be good or bad (Marr, 2015; Lohman et al., 2004).
- **Formulas, scales and assessment criteria** - In order to create uniformity around the data, the formula, scale or assessment criteria that will be used for the KPI should be specified. Depending on the what data is available and the purpose of the KPI there are several options. It could be a aggregated KPI, using a specific formula, index or a scale (Marr, 2015; Lohman et al., 2004).
- **Source of the data** - Where the data has it origins should be specified in order to assure of its reliability and validity (Marr, 2015; Lohman et al., 2004).
- **Data collection frequency** - The frequency of the data collection should be specified and thereby coordinate the dates when data is collected. According to Marr (2015) it is important know why the certain frequency is chosen in order to make sure that the data is only collected as often as it is actually needed.
- **Data reporting frequency** - The frequency of the data reporting should be specified and set. Furthermore, the data collection should be coordinated with the data reporting so that the data is as current and up-to-date as possible (Marr, 2015; Lohman et al., 2004).
- **Who measures and reviews the data** - The framework should specify one resource responsible for the data collection and updates, either a specific individual or a job title (Marr, 2015; Lohman et al., 2004).
- **Expiry and revision dates** - Each KPI should always include an expiry or revision date. Without it, KPIs can continue indefinitely and causing unnecessary work (Marr, 2015).

The last part, the validity of each KPI contains three elements. The first element refers how much the KPI will cost. Introducing and maintaining a KPI can be expensive and thus there needs to be an estimation of the cost to make sure that the added value is greater. Cost can include administrative or outsourcing costs for collecting data as well as analyzing it (Marr, 2015). The second element has the purpose to determine the confidence level in the KPI and therefore think of if it actually measure what is was designed to measure. The last element try to highlight the awareness of unintended consequences. Mapping of possible ways of manipulate the KPI which will allow the people using the KPI to consider better ways of collecting and assessing performance (Marr, 2015).

2.4 Logistics performance management in supply chain context

In previous sections, the concepts of performance measurement, PMS and KPIs in general was covered. This section here focuses on how the PMS should be adapted to the supply chain context in order to measure logistics performance, from various types of approaches. Narrowing it down into this is necessary, since the aim of this thesis was to investigate and give suggestions how to measure the logistics perfor-

	Example 1
Strategic Goal: *Name the strategic objective (from the strategy map), which is being assessed with this indicator.*	Grow Customer Satisfaction (Customer Perspective)
Audience / Access Name the key audience for this indicator and clarify who will have access rights to it	Board of Directors and Marketing Team
Key Performance Question(s): *Name the performance question(s) this indicator is helping to answer.*	To what extent are our customers satisfied with our service?
How will and won't this indicator be used? *Describe how the insights this indicator generates will be used and outline how this indicator will not be used.*	The indicator will be used to assess and report on our customer success internally. It will not be used to assess performance of individuals or to determine bonus payments.
Indicator Name: *Pick a short and clear indicator name.*	**Net Promoter Score**
Data Collection Method: *Describe how the data will be collected*	The data will be collected using a mail-based survey.
Assessment / Formula / Scale *Describe how performance levels will be determined. This can be qualitative, in which case the assessment criteria need to be identified, or it can be numerical or using a scale, in which case the formula or scales with categories need to be identified.*	Using a 0-10 scale (Not at all likely to extremely likely) participants answer: How likely are you to recommend us to a friend? NPS = pecentage of Promoters (score 9–10) – 5 of Detractors (score 0–6)
Targets and Performance Thresholds *Identification of targets, benchmarks, and thresholds for traffic lighting.*	55 per cent by the end of 2020
Source of Data *Describe where the data will come from.*	Survey of existing customers
Data Collection Frequency *Describe how frequently is this indicator will be collected. If possible, include a forward schedule.*	Monthly data collection – sampled 10 per cent of our customer data base
Reporting Frequency *Outline how frequently this indicator will be reported to the different audiences (if applicable).*	Monthly
Data Entry *Name the person or role responsible for collecting and updating the data?*	Ian Miller – Marketing Assistant
Expiry / Revision Date *Identify the date until when this indicator will be valid to or when it will have to be revised.*	24 months
Validate your KPI	
How much will it cost? *Estimate the costs incurred by introducing and maintaining this indicator.*	Costs are significant, but cheaper than a traditional customer satisfaction survey.
How complete is this indicator? *Briefly assess how well this indicator is helping to answer the associated key performance question and identify possible limitations.*	It provides us with a nice simple number, but the data should be supplemented with unstructured feedback about: What is particularly good? What could be improved?
Possible unintended consequences *Briefly describe how this indicator could influence the wrong behaviors or how people could cheat on this KPI.*	People could possibly influence customers before they take the survey or they could select customers who are likely to respond positively.

Figure 2.2: Example of KPI design template (Marr, 2015).

mance of a construction supply chain.

For a company that aims for a competitive position, it is critical to improve the logistics performance in its supply chain. Furthermore, the evaluation of logistics effectiveness and efficiency is gaining increased attention. By using performance measures, it helps managers to evaluate and develop the operations in the supply chain (Pettersson and Segerstedt, 2011). Dörnhöfer et al. (2016) define logistics performance management as the key to quantifying the current state and improvement potentials within logistics. Furthermore, a supply chain perspective needs to be included in today logistics PMS whose function is the provision of the physical link between companies within the supply chain. Although, except the importance of measuring the material flow, a monitoring of information process is perceived as significant, as the importance of information processes is rising, e.g. with shorter customer lead times (Dörnhöfer et al., 2016).

Senior Lecturer Ola Hultkrantz (Lecture on performance measurement, 28th September 2015) mention eight functions of performance measurements systems in the supply chain context.

- Translate supply chain strategy into operational objectives
- Provide supply chain managers with information and hence giving them the opportunity to react on identified performance gaps
- Communicate performance expectations across company boarders
- Clarify responsibilities and objectives between supply chain partners
- Support strategic decision making and prioritization in the supply chain
- Align objectives across the supply chain
- Motivate suppliers/partners
- Improve understanding of supply chain processes and how these processes are connected in a complex network of activities

As companies move towards a more integrated operations management function across the supply chain, it becomes necessary to measure the logistics performance of the different parts of the supply chain on various dimensions (Lohman et al., 2004). Logistics performance measurement should start at the supplier and reach until at least the assembly line of the original equipment manufacturer (Dörnhöfer et al., 2016). According (Lohman et al., 2004) the measurements should define and measure the performance of the supply chain as a whole. In order to understand causes of deviations of actual performance from targeted performance, each measure should be able to be drilled down to different measures and levels of detail (Lohman et al., 2004).

In order to measure logistics performance there are several views on how to structure the PMS in a supply chain context.

2.4.1 Resource, Output and Flexibility

Lohman et al. (2004) and Beamon (1999) suggest that PMS in a supply chain context should focus on three different types of measures in order to be sufficient. Each measure type has its goal and purpose connected to different crucial parts of the supply chain, see table 2.3 (Beamon, 1999).

Efficiency measures are connected to the performance measure type resources, i.e. to what degree the resources are utilized in the supply chain. These measures are often quantified as minimum requirement of resources needed. The output measures can visualize how well a company perform in terms of meeting customer demands. It could be number of defects, right quality and time etc. Although, there are some attributes that are hard to quantify in output which are of more qualitative nature, such as customer satisfaction. According to Beamon (1999), output performance measures must not only correspond to the organization's strategic goals, but must also correspond to the customers' goals and values. The flexibility measures should be able to measure a system's ability to cope with volume and schedule fluctuations from suppliers, manufacturers and customers. Although, flexibility is a measure of potential performance which derives from the other measures such as volume and delivery. All measures in the model corresponds and affect each other. Thus, it is important to have balance between them in order to achieve strategic goals of the company (Beamon, 1999).

Performance measure type	**Goal**	**Purpose**	**Example of performance measures**
Resources	High level of efficiency	Efficient resources management is critical to profitability	(1) Total cost (2) Distribution cost (3) Manufacturing cost (4) Inventory (5) Return on investment
Output	High level of customer service	Without acceptable output, customers will turn to other supply chains	(1) Sales (2) Profit (3) Fill rate of order (4) On-time deliveries (5) Backorder/stock-out (6) Customer response time (7) Manufacturing lead time (8) Shipping errors (9) Customer complaints
Flexibility	Ability to respond to a changing environment	In an uncertain environment, supply chains must be able to respond to change	No examples provided

Table 2.3: Key elements related to strategic goals (Beamon, 1999).

2.4.2 Performance of activity

Chan and Qi (2003) present a process-based model of supply chains, by which the supply chains are analyzed and measured, called performance of activity (POA). The supply chain should be viewed as one single entity and managed as a whole. Therefore, Chan and Qi (2003) suggest that the PMS should have a holistic view since not doing so might lead to local optimization instead of optimization of the whole chain.

In order to create the PMS, Chan and Qi (2003) suggest that the supply chain first should be analyzed according the process based approach. This means that the relationships and structures between the different actors should be mapped. The supply chain which is mapped, is viewed as one entity which consists of core-processes. That supply chain is then divided into several sub-processes, consisting of several activities (Chan and Qi, 2003).

When activities have been broken down and analyzed, performance measures should be assigned according the POA approach with aid of an proposed measurement board (Chan and Qi, 2003). Each measurement represents one dimension of activity or performance measurement type, see table 2.4. According Chan and Qi (2003) the performance measures dimension can be used to either categorize existing measure or function as a reference when creating new measures. Although, not all dimensions have to be included depending on what is suitable.

2.4.3 Supply Chain Operation Reference model

The SCOR model was developed by the Supply Chain Council in 1996 (Zhou et al., 2011). The SCOR model itself focuses on supply chain function from operational process perspective and includes customer-, market- and physical interactions (Zhou et al., 2011; Li et al., 2011). According to Zhou et al. (2011) and Thunberg and Persson (2014), the SCOR model is a powerful tool which is used in order to describe, analyze and improve a supply chain. Furthermore, it is proven to be applicable within several industries. However, Johansson and Persson (2011) claim that the SCOR model has to be adapted to the context where it will be used, in order to better embrace the characteristics of the construction industry.

Some of the perceived benefits with the model that has been documented within the manufacturing industry are faster cycle times, less inventories, improved visibility of the supply chain and access to important customer information in a timely fashion (Zhou et al., 2011). Based on surveys made by Huan et al. (2004), the SCOR model is considered to be the most promising model for supply chain strategic decision making.

The first step in the model is to map the current state and then introduce performance metrics. Thereafter, the model suggest to measure and analyze the current performance (Bolstorff and Rosenbaum, 2012). This means that the metrics that have been chosen should be calculated and evaluated. It is suggested to then try to improve the results from the current levels, and try to come up with target levels of the performance metrics. Furthermore it should be possible to estimate the value from such improvement.

In order to improve the supply chain, the SCOR model suggests to investigate possible best practices (Stephens, 2001). This step is described as a possibility to investigate these kind of best practices from other successful examples, thereby taking advantage of representative lists and candidate options for supply chain improvement (Stephens, 2001) .

Mapping of processes

Bolstorff and Rosenbaum (2012) describe the SCOR model by dividing it into three levels of process details. There is also a fourth level that is not contained in the

Performance measure type	Description
1. Cost	The financial expense to carry out one event or activity
2. Time	The time between the beginning and completion of one specific event or activity. Time is an important resource in modern business environments, especially where JIT and quick response prevails.
3. Capacity	The ability of one specific activity to fulfill a task or perform a required function
4. Capability	Ability of one activity to be used, treated, or developed for the specific purposes and required functions. Here four dimensions, which are most often used, can be identified with the purpose of covering the most important aspects of an activity's capability.
4.1 Effectiveness	The ability of one specific event or activity to achieve an intended or desired effect in performing the functions or taking the responsibilities
4.2 Reliability	The ability of one specific event or activity to perform a required function under stated conditions for a stated period of time
4.3 Availability	The ability to bring about effective or beneficial results or the degree to which one specific functional activity is ready when needed
4.4 Flexibility	The ability of one specific activity to adapt to the varying functional requirements or respond to the changes
5. Productivity	The rate at which one specific event or activity adds value at the cost of resources
6. Utilization	The utilizing rate of the resources to carry out one specific activity
7. Outcome	The results or value added of one specific activity and event

Table 2.4: The POA Metrics Board (Chan and Qi, 2003).

SCOR model, however it is necessary in order to implement improvements and managing the processes (Bolstorff and Rosenbaum, 2012). The first level in the SCOR model defines the number of supply chains, how they are measured, and also the necessary competitive requirements for this. Huan et al. (2004) state that level 1 is the top level of the model, and that it mainly deals with process types. The level is defined by the use of five supply chain processes, which are Plan, Source, Make, Deliver and Return (Bolstorff and Rosenbaum, 2012; Zhou et al., 2011).

The second level of the SCOR model is the configuration level, which deals with the different process categories and the core processes (Huan et al., 2004; Zhou et al., 2011). According to Bolstorff and Rosenbaum (2012), the second level uses the terms such as make-to-stock, make-to-order, and engineer-to-order to describe the processes. Level 3 is the deepest process level, which defines the best practices of each process (Zhou et al., 2011), but also the business processes and system functionality that is used in order to transact sales different kinds of orders, return authorizations and forecasts (Bolstorff and Rosenbaum, 2012).

- **Plan** - These types of processes include the supply resources that are being assessed, the demand requirements that are aggregated and prioritized, and the planning of inventory for distribution, production, and material requirements. Furthermore rough-cut capacity plans for all products and channels should be included in these kinds of processes (Bolstorff and Rosenbaum, 2012)

- **Source** - Sourcing processes contain the obtaining, receiving, inspecting, holding, issuing, and authorization of payments for raw materials and purchased finished goods (Bolstorff and Rosenbaum, 2012). Zhou et al. (2011) claim that the sourcing phase could be described as to where the manufacturer connects to the supplier.

- **Make** - Contains processes of requesting and receiving material, manufacturing and testing products, as well as packaging, holding and releasing products (Bolstorff and Rosenbaum, 2012). Zhou et al. (2011) state that this process includes the transformation of raw materials into finished goods, thereby meeting the supply chain demand in time.

- **Deliver** - This step includes the execution of the order management processes, as to where a customer- and product/price databases need to exist. Furthermore this step also consist of invoicing, warehouse processes, packaging instructions from customer specifications, consolidation of orders etc. (Bolstorff and Rosenbaum, 2012).

- **Return** - This process describes the products with defects are returned. This step also includes tasks as for example authorization, scheduling, inspection, verification of defective products and more (Bolstorff and Rosenbaum, 2012).

SCOR metrics

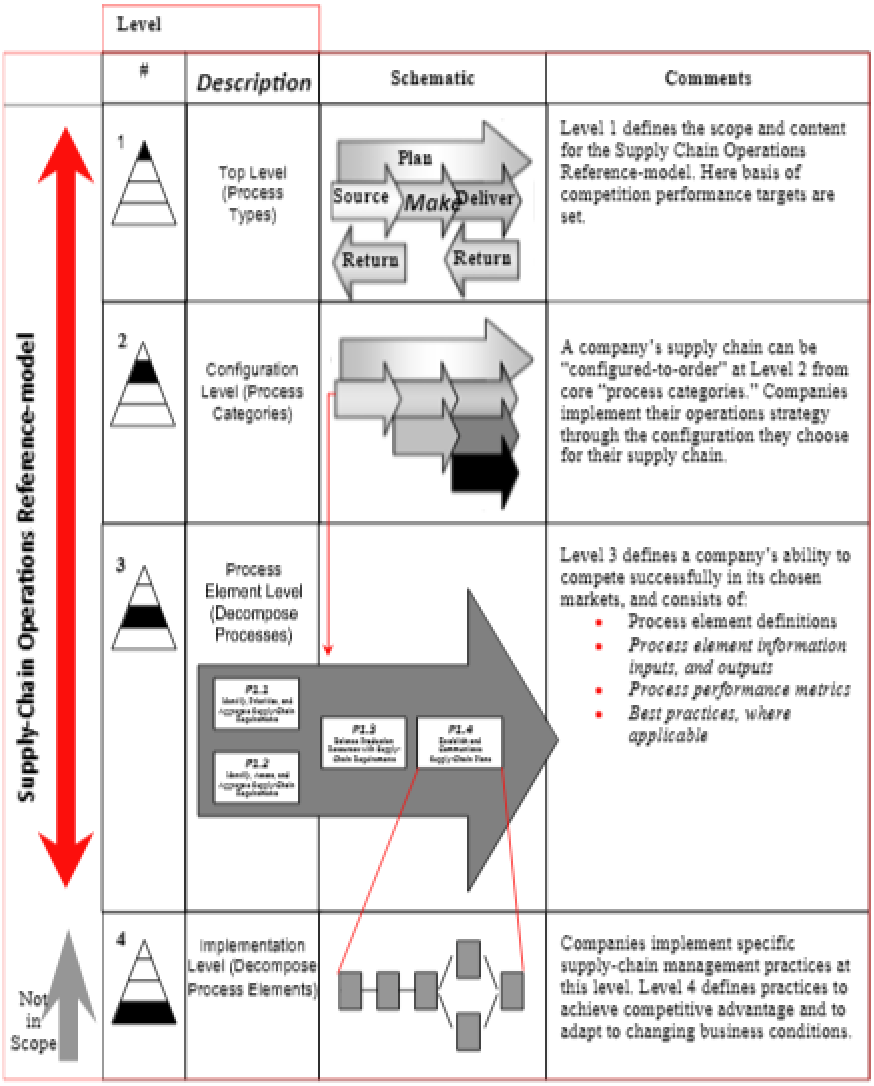


Figure 2.3: SCOR model (Zhou et al., 2011)

These metrics are split into two groups, customer-facing and internal-facing performance attributes. Customer facing attributes are then divided into supply chain-reliability, responsiveness and flexibility while internal attributes are divided into supply chain- cost and asset management efficiency (Persson and Araldi, 2009).

- **Supply chain reliability** - Measure the performance of the supply chain in delivering; the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer (Bolstorff and Rosenbaum, 2012).
- **Supply chain responsiveness** - Measure the speed at which a supply chain provides products to the customer (Bolstorff and Rosenbaum, 2012).
- **Supply chain agility** - Measure the agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage (Bolstorff

Performance attribute	Level 1 Strategic Metric
Supply Chain Reliability	(1) Perfect Order Fulfillment
Supply Chain Responsiveness	(1) Order Fulfillment Cycle Time
Supply Chain Agility	(1) Upside Supply Chain Flexibility (2) Upside Supply Chain adaptability (3) Downside Supply chain adaptability (4) Overall Value at Risk
Supply Chain Costs	(1) Supply Chain Management Cost (2) Cost of Goods Sold
Supply Chain Asset Management	(1) Cash-to-Cash Cycle time (2) Return on Supply Chain Fixed assets (3) Return on Working capital

Table 2.5: SCOR metrics (Bolstorff and Rosenbaum, 2012).

and Rosenbaum, 2012).

- **Supply chain cost** - Measure the costs associated with operating the supply chain (Bolstorff and Rosenbaum, 2012).
- **Supply chain asset management efficiency** - Measure the effectiveness of an organization in managing its assets to support demand satisfaction. Both fixed and working capital is included (Bolstorff and Rosenbaum, 2012).

2.5 Summary of theoretical findings

This chapter has provided the required theoretical findings in order to help to answer the research questions. First, the literature connected to the construction industry and supply chain management was reviewed. Thereby a foundation of knowledge about the construction industry was created, which was essential to answer both research questions in this report due to the construction and supply chain context. Furthermore, it was important to review literature regarding performance measurement and logistics performance management in supply chain context. Doing so, provided the necessary tools to create a conceptual framework (presented in chapter 5). The framework is based on a combination of literature recommendations, regarding what to consider and to include while developing a logistics PMS. Hence, it is connected to the first research question, *How should a logistics performance measurement system for a construction supply chain be designed?*. The logistics performance management along with the characteristics of the construction industry also gave the necessary foundation for identifying the right KPIs to include in the logistics development system. Thus, it's connected to the second research question, *Which KPIs should be included in a logistics performance measurement system of a construction supply chain?*

3
Method

This chapter describes in which way the research has been conducted, starting by explaining the research approach. The research approach describes step-by-step how this thesis was carried out. Next, an explanation of how data was collected and which sources of information that were used is provided.

3.1 Research Approach

The aim of this master thesis was to investigate and give suggestions on how to measure the logistics performance of a construction supply chain. In order to achieve this, the thesis should answer the two research questions: *How should a logistics performance measurement system for a construction supply chain be designed?* and *Which KPIs should be included in a logistics performance measurement system of a construction supply chain?*. Following these research questions led to the research approach that can be seen in figure 3.1. There a flowchart is presented of how the research was performed, and describing the different steps of this thesis.

In order to design a logistics PMS for a construction supply chain, a case study was conducted at Inköp AB. That case study worked as a practical validity of the literature findings (Yin, 2003). As can be seen in the flowchart in figure 3.1, the case study was performed in parallel with a literature study. The literature study was conducted in order to ascertain a basic approach and was carried out by gathering previous research contribution and potential approaches. Thereby, it was aimed to identify the most appropriate ways of measuring the logistics performance in supply chains. The literature study covered several different areas, e.g. the construction industry, supply chain management, and performance measurement systems. The literature study was done in order to gain deeper knowledge within the chosen area of research. A majority of existing theories have their starting point from the manufacturing industry. In order to create a valid foundation for this research, these types of theories were combined with research covering construction industry characteristics.

Since the aim and research questions of this master thesis mainly concerned the development of a logistics PMS, a qualitative research approach was chosen as the most suitable option. Using qualitative research in this master thesis was deemed suitable since access to human resources with the appropriate knowledge was given.

As already mentioned, the case study was conducted in parallel with the literature study. One of the reasons why Inköp AB was chosen as a case company was its connection to one of the largest construction companies in Sweden, in this report called Bygg AB. Another aspect that made Inköp AB interesting was the fact that it sourced products from abroad. In case studies, the interest in what is happening in the environment is considered, but also the explanations why these events occur (Denscombe, 2014). The single case study in this thesis was conducted during 20 weeks. According to Bryman and Bell (2015), there are mostly some clear restrictions regarding both time and opportunity for collecting data. A case study is by Merriam and Tisdell (2015) described as an "in depth description and analysis of a bounded system". Some advantages when conducting case studies are the possibilities to investigate problems that appeared in a real life situation at the case study. However, Merriam and Tisdell (2015) state that one of the main limits to the quality of a case-study is the characteristics of the researchers. This means that the researcher is seen as the tool for collection and analysis of data. Another point is that with single case studies, it is difficult to generalize findings since the study only has been applied to one specific context. Furthermore, single case studies can not use comparisons in the same way as multiple case studies. On the other hand, Merriam and Tisdell (2015) indicate that results still can be used for further research within a topic, and claims that the impact of single case studies are widely underestimated. Merriam and Tisdell (2015) also state that one advantage in single case studies is the possibility to gather in-depth data.

The case company that was examined in this master thesis should be considered as a typical actor in a construction supply chain. However, the case company also had some unusual characteristics. For example, the company was a purchasing department within a large actor of the construction industry. The case company was there responsible for sourcing different types of product categories solely from low-cost countries.

As can be seen in figure 3.1, the case study consisted of first conducting some interviews, where mainly knowledgeable people within the industry and the case company were interviewed. By analyzing the gathered data from the interviews, a supply chain mapping could be conducted. This was done in order to understand the context of the case company Inköp AB, and clarify possible problem areas. Furthermore, by conducting a supply chain mapping it gave an overview and understanding of the supply chain and the business processes of Inköp AB. In this step, the current PMS and KPIs that were used at Inköp AB were also identified, including their definition, and their actual and targeted levels. The supply chain mapping followed the SCOR model, which was one of the early literature findings. The SCOR model was conducted at a higher level of details, meaning it only mapped out which actors and processes that the supply chain contained.

The next step that can be seen in figure 3.1 was to connect the literature findings and the empirical data that was collected in the context of the case study. There an initial list of suitable KPIs that should be the foundation of the logistics PMS were "cherry picked" from literature. "Cherry picked" means that research in the literature was made, were the best parts were identified and applied to the framework of this thesis. However, the KPIs were also chosen in consensus of the output of the interviews and supply chain mapping that made up parts of the empirical findings.

Next, a conceptual framework was created, which focused on the design of a logistics PMS and tried to answer the research question *"How should a logistics performance measurement system for a construction supply chain be designed?"*. The framework was developed by conducting an intense literature study, and was based on a combination of literature recommendations of what to consider and to include when designing a logistics PMS.

The final step of the flowchart that is presented in figure 3.1 was initiated by the validation of the findings that had been made up to that point. This was done by interviewing a group of knowledgeable people within the organization of the case company. The interviews with this group were semi-structured, with a lot of possibilities for free discussions. By analyzing the output of the interviews with the reference group, it was possible to identify what a construction supply chain should focus on. The input of the second interview round then led to the designing of a logistics PMS for construction supply chains. Thereby it was possible to answer the research question: *"Which KPIs should be included in a logistics PMS of a construction supply chain?"*.

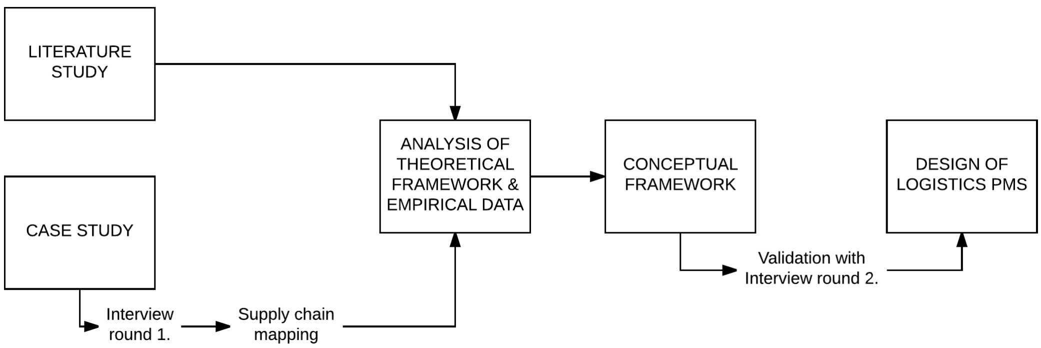


Figure 3.1: Flowchart visualizing the research design

3.2 Data Collection

A number of different methods and sources were used for collecting data. In order to find relevant literature for this thesis, keywords related to the research question were used in common scientific portals and journals such as ScienceDirect, Elsevier, and Emerald Insight. Some of the used keywords were: *construction industry, supply chain management, construction supply chain management, performance measurement systems, and SCOR model.*

For the case study, data was collected through interviews and through accessing various databases at Inköp AB. These databases consisted of all types of data, including order lists and information about incoterm agreements, as well as business plan and strategies. The interviews were conducted with employees from Inköp AB and from the logistics and supplier management department of Bygg AB, as can be seen in table 3.1. Saunders et al. (2016) describe three different ways that an interview can be structured, which are: structured, semi-structured and unstructured. The interviews for this report were generally semi-structured in depth interviews, thereby enabling focus on the topic of this research. The interviews were prepared by having a set of questions which were used as guidelines through the interview, see appendix B. Conducting semi-structured interviews also allowed for possibilities in the conversation to learn more about experiences and opinions of the interviewee, and helped amplifying the boundaries of questions, depending on the participants answers. Data based on interviews can be influenced by personal opinions, interests and different backgrounds. Semi-structured interviews help to cover as many relevant aspects as possible, since it is difficult to map and replicate whole interview discussions and impressions. Nevertheless, the level of research was kept as detailed as possible. This was done by following the questions in the appendix and by attempting to reproduce main statements, basic impressions, opinions and conclusions within the empirical study. To further improve the reliability and prevent the loss of information, the interviews were often structured in a way that one of the interviewers was writing while the other was asking questions. In some cases the interviews were recorded, thereby allowing both interviewers to fully focus on the interview process.

Role	**Actor**
Responsible for framework agreement with the 3PL	Inköp AB
Analyst from the logistics group	Bygg AB
Handling orders from Sweden, Norway and Finland, selects the right supplier for the right reinforcement type	Bygg AB
Order management	International office of Inköp AB
Supplier Management	International office of Inköp AB
Business analyst for reinforcement	Inköp AB
CEO	Inköp AB

Table 3.1: Interviewees for the first round of interviews

The people that were chosen for the interviews can be seen in table 3.1 and 3.2, and consists of employees from Inköp AB and Bygg AB. The interviewees could be seen as experts in their different areas of expertise, and should be considered as well informed about the construction industry in general. Roles and number of interviews was decided together with Inköp AB's management in order to get enough expertise covered. Furthermore, at each conducted interview, the interviewees were consulted regarding the chosen people for the reference group. The conceptual framework in this report was used as a foundation for how to design a logistics PMS, thereby also influencing the interview questions that were chosen. Before most of the interviews, information was sent out in order to prepare the interviewees and give them an indication on what to expect. Interviews were conducted both face-to-face and through Skype, with a varying length between 30-60 minutes. The number of interviews conducted with every interviewee was between one to two occasions.

Table 3.1 shows the group of people which were used in the first interviewees, in order to map the supply chain and understand the context of Inköp AB and Bygg AB. On the other hand, table 3.2 presents the interviewees that were used in order to validate the findings after the case and literature study had been conducted. The interviews with the reference group generally were a little longer since more content was covered. Furthermore, the interviews with the reference group did generally contain more freedom, meaning that there was a little more room for discussions. During the interviews with the reference groups, theoretical definitions of KPIs were described by using applicable examples. Thereby it became easier to relate it for the interviewees. Following this procedure should facilitate the comparisons of data, since it ensures that the circumstances during the interviews were similar for several interviews.

Role	**Actor**
Head of supplier management	Inköp AB
Purchasing leader	Bygg AB
Category manager transports	Bygg AB
Project manager supplier development	Bygg AB
Business solution manager procurement and logistics supplier management	Bygg AB
Green business developer	Bygg AB
Category manager	Inköp AB
Partnering leading supplier	Bygg AB
CEO	Inköp AB

Table 3.2: Interviewees, second round - reference group to validate KPIs

In order to answer the research question, the data which was gathered from interviews, literature, and from the case study at Inköp AB, was compared and analyzed. The starting point for this master thesis was given by conducting interviews and understanding the main problems of Inköp AB. Furthermore, the conceptual framework that was created from theory, was used as a foundation for the analysis. The conceptual framework clearly shows how the findings from the case study and the literature should be used in order to draw conclusions for the analysis.

Another aspect of the data analysis was the possibility to test the validity of the findings. Yin (2003) describes and divides validity into construct, internal, and external validity. Construct validity considers the correctness of the data for the study. Unclear information or data that seemed incomplete was sent to the respondents in order to validate and cover information gaps. External validity is described as the possibility to generalize findings, thereby ensuring that outcomes can be applied to other contexts. The data that was analyzed in this master thesis was mainly based on one company, but also included a wider view of the industry by gathering theoretical findings. Thus, the study aimed to develop a framework that was applicable for other companies within the construction industry as well. Internal validity is stated as the evidence of inferences made from primary data as interviews. To approve this aspect, interviews were conducted in order to understand the situation and to prove the applicability of theoretical findings.

4
Empirical data

This chapter primarily seeks to introduce the context of the case company which was used for this report. The company will be thoroughly introduced and described, thereby providing the foundation for the analysis together with the theoretical findings from the previous chapter. The empirical data will also contain the case company's structure, their strategic objectives, as well as giving an explanation of the current KPIs that were suggested, and how the PMS is structured. Furthermore, a supply chain mapping of the company will be presented, where the main implications and problems of the case company are described.

4.1 Provided products

As it is today, Inköp AB offers four type of product categories to their customers.

- Reinforcement
- Natural stone
- Tarpaulins
- Cabinets

Reinforcement as a product category stand for the majority of the turn-over within Inköp AB, and is divided into five product groups. The product groups differ in terms of added production cost at the material supplier, meaning that some require more prefabrication than others. Recently, the trend has been to increase the volumes of the prefabricated products, since this puts more work in low-cost countries and thereby decreases the total production costs. However, as stated in interviews, the physical characteristics of these products has affected the transport efficiency negatively, since they are more difficult to consolidate and load into a truck. In the end this means that the fill rate with prefabricated products is lower, leading to less tonnage per transport and a higher transportation cost.

Overall, importing reinforcement products via Inköp AB has had a great effect on changing the Nordic market of Bygg AB's projects and pushing the competitors to lowering their prices. A couple of years ago, the price differences were huge between the market in low cost countries and the Swedish market. However, they have nowadays decreased because of different reasons, e.g. lower prices from Swedish competitors and inflation and taxation's etc. Since this has happened reinforcement can be considered to be mature.

4.2 Strategic plan and objectives

Bygg AB's recently updated business plan had the overall theme, "profit with purpose". Since Bygg AB has identified purchasing as a function with great potential and implications on the profit, it is of highest importance to realize this potential from a strategic point of view. Part of this potential lays in international purchasing and challenging supplier structures within the Nordic countries. Inköp AB plays an important role when it comes to realizing this potential and reaching the results stated in the overall business plan from Bygg AB but also for purchasing as a function. Therefore, Inköp AB also need further development. Bygg AB has a strategic objective to create sustainability in the supplier base. This has also influenced Inköp AB to become "greener" and to become more sustainable, since they also are part of Bygg AB.

To reach the expected results, a strategic plan was created. The purpose of Inköp AB's strategic objectives is to clarify what the targets for the future are, and by stating the objectives also aligning these with the process of achieving these goals. For Inköp AB, the main ambition is to become a world class purchasing department and at the same time maintain a cost efficient purchasing function. There are currently nine different strategic areas at Inköp AB, where they have been divided and grouped into different segments. The nine different areas is based on the overall goal of increased efficiency which is stated as;

"Through clear responsibilities, goals, measures and follow ups the efficiency shall increase. There is a clear need to be more visible in projects, market products more and spread more knowledge. This will be part of the ambition for 2020."

Three of the identified strategic areas had connection to the supply chain topic and was labeled as "Suppliers", "Logistics" and "Products".

4.2.1 Supply chain strategic areas

For Logistics there are strategic objectives regarding the logistics, where two goals for 2020 have been stated:

- Achieve a delivery precision of 99 %
- Have an average weight of at least 20 tonnes per truck, maximum is 24 ton

Furthermore, Inköp AB have identified a couple of improvement areas or way forward for Logistics in order to reach the ambition for 2020.

- Reduce risk of delays from manufactures. For some suppliers there must exist routines/procedures how to handle/avoid delays.
- Establish structured way of working with supplier development to increase performance in quality and delivery

- Investigate how to consolidate volumes in a different way to get up tonnage as well as efficiency
- Closer cooperation with manufacturer regarding material loading plan and truck amount. Continuous dialog with projects and suppliers concerning circumstances of delivery and needs.

For Products the goal for 2020 is to increase the amount of different products within Inköp AB to get a greater width and increase the competitiveness for Bygg AB. As mentioned before, Inköp AB has the ambition to increase volumes of prefabricated products since the total cost for the projects within Bygg AB would decrease. Since the product variety and volumes has the goal to increase, this also necessitates a broader supplier base and at least dual sourcing setups for each new product. Furthermore, the products that are bought shall to the largest extent be bought from companies that have the lowest total cost including freight.

4.3 Supply chain mapping - processes and actors

A supply chain mapping was conducted in order to create an overview of Inköp AB's supply chain. The mapping had a number of uses. First, it should help clarify what the current state of the company looks like, how the different processes of the different actors are designed, and help explaining where and what the main problem areas are. The mapping which is presented below, was developed by following the SCOR model, which means that the processes were divided into three levels of detail. As described in the theory, the top level consists of four possible types of processes (Make, Deliver, Plan, Source and Return), which are more broken down into more detail processes in level 2 and level 3.

In figure 4.1 the four different actors are presented. The material supplier is responsible for producing the reinforcement in accordance to technical specifications. These technical specifications are first discussed between the project site and Inköp AB, and then later communicated to the supplier. There are currently five different types of reinforcement, which all can be further modified according to the project site's wishes. The other actors in figure 4.1 are a 3PL which is responsible for the transportation of goods, Inköp AB, and the project site. In the following paragraphs the processes of the different actors will be presented. For deeper level of detail, see the entire supply chain mapping (using the SCOR-model), which is presented in Appendix A.

4.3.1 A - Material Suppliers

Inköp AB currently uses twelve material suppliers for the product category reinforcement. Usually, the suppliers receive a call or an e-mail from Inköp AB, where a purchase order has been made. This purchase order should contain information about the order, such as volume, product type, delivery date, and technical specifications that might require some customization. Depending on the amount of

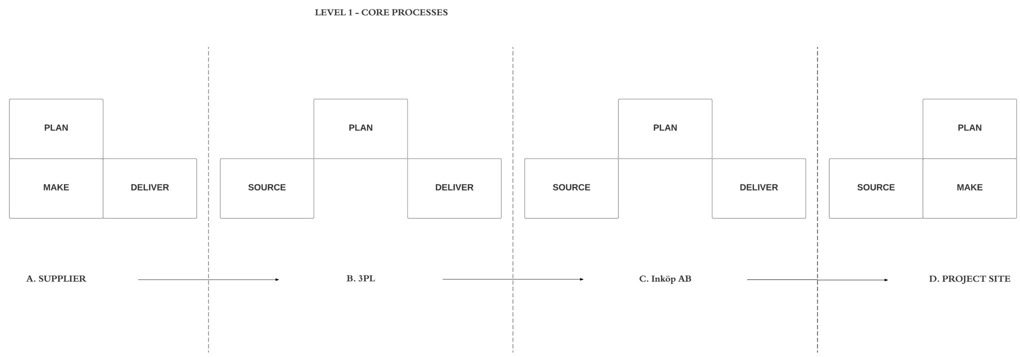


Figure 4.1: SCOR Model, Core processes - Level 1

customization that is required, the production can be seen as either make-to-order or engineer-to-order. In either case, the material supplier evaluates the order and creates a production plan, and communicating agreement to Inköp AB that the purchase order has been agreed to and will be fulfilled on time. The material supplier furthermore needs to plan raw material requirements and plan its production schedule in order to being able to finish the order on time. Since the delivery date has been set, the material supplier needs to communicate with the 3PL regarding the pick up date at the manufacturing plant. In general the 3PL has calculated that the lead time for transporting goods to projects are two days, thereby requiring the trucks to arrive at the production at least two days before set delivery date. On set date, the material suppliers normally have allocated a time window of four hours in which the trucks are allowed to use for loading the goods. The loading is there following specific requirements, made by both the truck driver and the project site which should ensure safety when unloading and transporting the goods. However, one interviewee claimed that the truck driver has the most power, since he is allowed to decide how the truck should be loaded. When the material suppliers have ensured that the goods have been delivered, the invoice for the order will be sent.

4.3.2 B - 3PL

The next step in the supply chain is the transportation of goods, where a 3PL is responsible. Inköp AB communicates by mail or phone with both the project site and the supplier and agrees to a certain date and time for the delivery at the project site. Thereafter Inköp AB mediates the information to the 3PL who has to confirm to the terms and conditions. The 3PL and the supplier can then decide on their own which exact date and time that suits both parties best. However, the 3PL is responsible for delivering the goods on the correct date and time. On the date of pick up, the 3PL has a time window of four hours (can be negotiated) to arrive and load the truck in accordance to packaging requirements from both a project- and from a safety perspective. Thereafter the truck transports the goods to the project site, where the goods are unloaded and the 3PL currently measures if the transport was performed on time.

The contracts with the 3PL builds on a framework agreement with the incoterms FCA (Free Carrier), which means that the 3PL is liable for the goods during transportation. However, it has been stated that no targets for any types of KPIs have been negotiated in the framework agreement.

4.3.3 C - Inköp AB

The main task of Inköp AB is to meet the requirements from the project site, source the required goods at a low price from a low-cost country, and to succesfully coordinate the material flow so that the orders are sucessfully fulfilled at the right quality and on-time. Whenever a new order is created, Inköp AB has to manually contact the preferred supplier and check whether it is possible for the supplier to fulfill the order. When the supplier has agreed to this, Inköp AB contacts the 3PL in order to book a transport. The current orders are inserted in a ERP system, where the delivery schedule for the projects are created.

When a defect or mistake is noticed at the project site, the project makes a claim. Inköp AB then takes on the responsibility of trying to solve the problem that has appeared. However, according to one Interviewee, the claim is never black or white, meaning it is extremely difficult to proof where the mistake or fault has been made and who should be held accountable. This makes it very difficult for Inköp AB, since there then can not be made any proactive adjustment. Instead the only option is to take reactive actions, which mostly refers to only adjusting the problem, but not being able to achieve full financial compensation.

When selecting which suppliers to use, Inköp AB invite suitable suppliers to a e-auction. This means that the most important attribute to become a preferred supplier for Inköp AB is to have the lowest price. However, there is a some requirements which suppliers need to fulfill before qualifying for the e-auction, thereby securing certain quality standards. These suppliers do then not have any logistics specifications or targets which they need to fulfill. Instead they only have a framework agreement which decides price, how long lead time the supplier has between order and finished production, and the time period of the contract. Furthermore, the suppliers provide a price list for the projects how much it cost per weight to transport the reinforcement to the project site.

Inköp AB's satisfaction of their suppliers varies. In most cases, Inköp AB are happy with their suppliers, with whom they often have a long relationship with, and which they have worked with for several years. However, over time some problems have occurred. These problems are mostly regarding the transportation of goods, where it happens that the goods sometimes arrive late at the project site. Furthermore some packaging issues have been reported, which has led to some safety issues when unloading the goods at the project site. There is currently no supplier development program in use, but Inköp AB instead seek to put a lot of effort into training the suppliers, and to explain to them how to produce and how to ensure that the processes are carried out correctly. In some cases Inköp AB decides to visit the material suppliers in order to perform quality checks. New suppliers usually have a so called test period, which lasts for about six months. During this time the performance of the supplier is evaluated by giving them some orders with less quantities.

4.4 Customer perspective

For Inköp AB, it should be of the highest importance to satisfy the customers, meaning the projects that order the products. In order to do so, Inköp AB has stated some points that the projects should be able to expect when ordering from Inköp AB. These were among others to have competitive prices, provide products with good quality, have reliable supplies and delivery precision, be easy to order for the customer and accessible. Furthermore Inköp AB wants to provide the projects with reliable and controlled suppliers, and wants to be a support or speaking partner if the projects need it.

Around 50 project sites in Finland, Sweden and Norway have during the last 4 years been part of a survey, where the performance of Inköp AB and other suppliers of Bygg AB were evaluated. The projects there had 11 different indicators which they used to evaluate Inköp ABs performance. These indicators were:

- Attitude towards safety
- Cleanliness
- Compliance with safety instructions
- Representatives/supervisor's availability and expertise
- Compliance with agreed timetables
- Unfounded demands related to the contract
- Billing and terms
- Contract compliance
- Quality of the products / performance
- Development activity
- Reactions and corrective actions towards claims/remarks

The results showed that Inköp AB got relatively low scores, and had a lower degree than the suppliers of Bygg AB in almost all categories, for the last four years. The only category were Inköp AB were slightly above the other suppliers was for the quality of the products. However, it should be noted that Inköp AB in 2017 slightly improved in the ratings from the projects.

4.5 Performance measurement system Inköp AB

Currently Inköp AB needs a standardized PMS for logistics. There are only a small amount of KPIs for logistics, which is seen as a major reason to why employees in the company do not know how well they are performing logistics wise. There are in total ten KPIs reported towards Inköp AB's board, as can be seen in table 4.1.

KPI
EBIT +/- 0
Delivery performance
Quality
Deliveries (ton) - SE
Deliveries (ton) - NO
Deliveries (ton) - FI
Market share - Bygg AB SE %
Market share - Bygg AB NO %
Market share - Bygg AB FI %
Recommendations in project evalutations

Table 4.1: KPIs reported to Inköp AB board

Two of the KPIs refer to the measurement of the logistics process; quality and delivery performance. The quality KPI measures the amount of goods which is exactly as required specifications from the material supplier. This could be if the shapes, diameters, bending grades, molded right, goods way of handling or if the length is correct. The measurement is based on project remarks which is collected by Inköp AB and then calculated in Excel.

Delivery performance measure if the transports is being on time to the project. The measurement is on the 3PL but done by Inköp AB, were they collect all the data and calculate manually in Excel. For example, if the truck is late, this is noted and then based on the notes a monthly list is created to get an overview. Inköp AB has measured the delivery precision in general to be over 90 % according one of the interviewees, even close to 95 %. However, the delivery times could sometimes get postponed a little, since some packaging issues could occur when loading goods for different projects and trying to consolidate. Furthermore, it is important to note that this kind of delivery precision only takes into account if the truck is on time, not if the entire order was correct.

Furthermore, according interviews fill rate of the trucks is also measured at an operational level manually, but it is not a reported KPI if not asked of. Fill rate is measured by collecting data every month about the amount of tonnage and amount of transports. Tonnes per transport is then calculated. The fill rate depends on type of goods and month or demand. For example, if a product is of more prefabricated character, then the fill rate will be lower since each unit take a lot of space.

4.6 Discussion regarding proposed KPIs

After having created an initial list of KPIs, interviews were conducted with a reference group. As mentioned before, the reference group consisted of both members from Inköp AB and Bygg AB. The objective of these interviews was to validate the findings, create a final list of the identified KPIs, review the framework and template included in the so called "KPI scorecard", and to identify what strategic and operational KPIs that should be used under each performance attribute. The initial list of KPIs that was used as a foundation before interviewing the reference group can be seen in figure 4.2.

4.6.1 Perfect Order Fulfillment

Perfect order fulfillment (POF) would, according to all members of the reference group, be the most powerful KPI to implement. The reason for this is that the KPI covers so much information, and involves many aspects. The KPI includes both where and what in the supply chain something is wrong, but also states which actor is responsible.

The general feedback for this KPI has been the potential issues in implementing it, since it would require a lot of data and input from several actors. The questions, what does this require, how should the data be collected and who should be responsible for reporting in, was stated in several interviews. At other parts of Bygg AB, suppliers measure themselves and report into the Bygg AB system. Furthermore, there is a lack of motivation among projects at Bygg AB to report in when there is a deviation. This is according interviewees a generic problem at Bygg AB since it doesn't exist a standardized process for this. In total, there has been two reported deviations in the last six months. One suggestion to simplify the reporting process is to make it digital. Have a tag, survey or use some kind of system where the project manager should just check if everything has been done correctly. In order to further motivate the projects to report in data, the projects should be able to access this data as well. Another potential issue with the KPI could be the criteria in checking if the quantity was right. It is hard for the project to control if the exact amount of tonnage was delivered, this is something that is often discovered later when production is ongoing. One of the interviewees stated: *"What happens if the issue is discovered much later, e.g. two weeks after the delivery?"*. For this case the issue would have to be reported in afterwards, thereby updating the initial reported

Supply Chain Dimension	Strategic KPI	Purpose (KPQ)	Operational KPI
Supply Chain Reliability	Perfect Order Fulfillment (POF)	- Where, what and why is there an issue causing an incomplete order towards the project?	- Material supplier ready at ATP check -3PL ready at ATP check -Successful delivery at project site
	Quality Index	-What is the ability of our products to meet customer expectations?	- Meet technical requirements of order (per product group) -Customer complaints (%) due to quality of products
Supply Chain Efficiency	Fill rate per truck	- How efficient are we when using truck capacity and consolidating orders?	- Tonnes per truck (per product group mix)
	Transportation cost per ton	-What is the cost of transporting our products?	- Transportation cost per ton (per product group or mix)
Supply Chain Responsiveness	Order fulfillment cycle time	- What is the responsiveness towards our customers?	-Source CT -Make CT -Delivery CT
	Backlog	- How many orders do we currently have that are not fulfilled yet?	-Backlog orders -Backorders -Order intake
Supply Chain Sustainability	CO2 Emission per ton-km	-How "green" is our supply chain?	-Supply chain miles - CO2 Emission ton /truck

Figure 4.2: Initial list of KPIs

data.

One of the main points of discussion during the interviews with the reference group was the criteria that was intended to be included in the KPI. The five criteria that was included was:

- Time
- Packaging of product
- Quality
- Quantity
- Documentation

The remarks that some of the interviewees had was that it needed to be stated exactly how the data collection was to be made, since both Bygg AB and Inköp AB historically had trouble with continously and precisely measuring data. However, the interviewees approved of the criteria and believed that it would be very beneficial to the company, if the data collection would be done correctly.

4.6.2 Quality index

Quality index had a mixed response among the reference group, some in favor and some against. Quality in terms of measuring the quality of the products delivered is an important aspect. However, some questions where raised if it is necessary to have it as a strategic KPI, where some of the reference group on instead suggested to have it as an operational KPI, underlying to perfect order fulfillment. One of the interviewees stated that: *"You will always get a WHY when presenting KPIs, so the KPI needs to cover a lot"*. Regarding the issue from this perspective led to the conclusion that quality should be more appropriate to have as an operational KPI, connected to the perfect order fulfillment instead. Thereby it was believed that the POF would be strengthened, since it would cover all the necessary aspects thoroughly.

4.6.3 Fill rate

The majority of the members in the reference group agreed that fill rate is an important indicator to measure, since it is deemed to have a big impact on both the economy and environmental sustainability of the supply chain. Currently, Inköp AB buys full truck loads (FTL), which means that they order the entire trailer from the 3PL and are themselves responsible for consolidating the transport. The reason why fill rate affects the economy so much is that all transports of Inköp AB comes from outside of Sweden. Having a low fill rate therefore means a very high transportation costs for each order, and should therefore be avoided as much as possible.

In the discussions with the reference group it was mentioned that optimizing the fill rate is a good idea. However, one interviewee was quoted: *"What is the target for the KPI? Is it to have 80 % fill rate, or is it to maximize the target and to achieve 100 %?"*. This refers to the fact that it in some cases might exist a trade-off, thereby affecting the service level of Inköp AB. From that perspective, some other comments in the discussions were that it sometimes might be beneficial to have a lower fill rate for some transports, since the company in some cases would rather have a low fill rate than have a decrease in service level. Furthermore, the fill rate also depends on the type of product that is being transported. For example, straight reinforcement that weigh a lot, are much easier to fit in a truck than products that are lighter and require a lot of space. It was also concluded that it is important to know what the target for the indicator should be, and who should be responsible for increasing the fill rate. For example, it could be an incitement to try to get the project to buy more (or a little less) material so that the trucks get a higher fill rate. On the other hand, it might not always be possible to order trucks with higher fill rate, since there is a limited space available at the project site. It was also mentioned that if possible, Inköp AB currently wants to consolidate orders from different projects. However, it is not always realistic since the trucks need to get to the ferry on time, and have a specific date and time that they need to deliver the goods to.

4.6.4 Transportation cost per ton

Similar to fill rate, this KPI also lies under the category "supply chain efficiency". The discussions for this KPI were therefore somewhat aligned with what was said about fill rate. This KPI was initially called transportation cost per ton and intended to just measure the cost for transports in regard to the weight in the truck. However, by discussing this with parts of the reference groups, it was concluded that doing so would neglect an important factor, which is the distance. If a transport e.g. would have a destination that was 2000 km further away than another route, the transportation costs there would be much higher. In order to therefore achieve a cost that could give a good comparisons for all kind of different customers, transportation cost per ton-km was developed.

Transportation cost per ton-km is seen as an useful KPI, since it is an indicator that compares the costs of the transportation, depending on how far the truck has to go, what fill rate the truck has and how difficult the product is to consolidate and load in a truck. One aspect of this KPI was also considered to be the possibility to give the project real data on how much the transportation really costs, thereby displaying to the customer the cost advantages when ordering full trucks, compared to having too many small and expensive orders.

Another interesting thought that came up during the interviews was to use the results from transportation cost per ton-km and analyze and compare it with the results for fill rate. According to one of the interviewees, this kind of analysis would be very interesting to schedule quarterly and asked: *"How much money can be saved by increasing the fill rate?"*. For example, if the fill rate would be increased from 60 % to 80 %, the transportation cost per ton-km would also be considerably lower. By measuring the transportation cost per ton-km and analyzing it together with fill rate, a tremendous cost-analysis for the transports should be possible to compile.

The main discussion regarding this KPI was if it should be a strategic or operational KPI. The general opinion was to have just one of the two KPIs, fill rate and transportation cost, as a strategic KPI. That would mean that the other one would be an underlying, operational KPI. The advantages of transportation cost is that it adds a total cost perspective to the transportation of goods, making the costs visible to the actors in the supply chain. However, fill rate might be the more suitable KPI to have as a strategic indicator, since it is easier to affect and have strategic objectives for. The transportation cost depends on a number of different aspects, thereby making it difficult to on a strategic level to analyze whether the current result is good or not.

4.6.5 Backlog

The majority of the members in the reference group agreed that backlog is an important KPI to measure. It shows how a company respond to their customers orders but also what is the load on the capacity. Furthermore, since the KPIs input data exist today in the current system, the difficulties in implementation would be quite low. Although, it was proposed that it shouldn't just cover the number of orders, but also include a volume factor or tonnes. This would then give a more fair view of the current situation in terms of responsiveness towards customers.

In order to complete the backlog KPI, two underlying, operational KPIs were discussed. According to some of the interviewees, measuring how many unbooked orders that Inköp AB currently has would be of interest. This would mean measuring the orders that would not had been allocated towards a supplier, or where the 3PL had not been scheduled yet. Thus it would be possible to really understand the current strain on the company, since those would be the orders that not yet would be fully confirmed yet. The other operational KPI that was discussed was backorder, which should measure the amount of orders that the case company has received, but has not yet shipped and are late.

4.6.6 Order Fulfillment Cycle Time

Order fulfillment cycle time had a mixed response among the reference group, some in favor and some against. It is important to consider the time aspect towards the customers and if there is a potential to decrease it. Although, it depends a lot on the ordering pattern from the customers, how long before orders are ordered and if actors are requesting short lead times. It was discussed that some customers would order six months before the order should be delivered, while other projects ordered the week before. One suggestion that was made was to reformulate it into how often that the original stated order lead times are met.

In discussions with interviewees, one example was to measure the time between that the first order arrives from the project site until the delivery date had been confirmed. Furthermore, one of the interviews was skeptical towards order fulfillment cycle time, and instead asked: *"Is it possible to measure how the ordering patterns of the customers look like?"*. This was concluded to be an interesting and valid request, which led to that order fulfillment cycle time was replaced by a strategic KPI called customer ordering lead time. This KPI should measure how long before the requested delivery date that an order was made, thereby viusalizing the ordering patterns of customers.

4.6.7 CO2 emission ton-km / product

The majority of the members in the reference group agreed that CO2 emission ton-km / product is an important KPI to measure. In the future, this will be very important towards the projects since the end customer (often government) values green solutions. For Bygg AB this is a very important aspect, which indirectly affect Inköp AB. Currently, there is no KPI at Inköp AB which considers sustainable green targets. Therefore, the decisions taken is not influenced by this perspective when e.g. choosing suppliers. Although, according interviewee's this could influence the decision where to source from geographically. One interesting statement from one of the interviewees was: *What do we measure? Can we compare the result with something? Is the result good or bad?"*. According to that interviewee, the result of the KPI therefore should be aligned with what other industries measure, or be clear enough so that the receiver of the KPI should understand the result.

In order to provide value for the customers, it should be possible to break down this KPI per product. The reason for this is that the projects want to know how much emission the products that they order have on the environment, due to the transport. Weight of load should be included, since the truck has a lot more emission of it is a heavy loaded truck. Furthermore, in the future it could be interesting to include NoX (nitrogen oxides) as a measurement. This is dependent on the type of vehicles that is used. For example, Euro 5 and Euro 6 trucks could be used, which are modern trucks that have low emission rate. Percent of sustainable vehicle fleet could be used, meaning the percentile usage of Euro 5 and Euro 6, but is not directly affecting the CO2 emission. Euro 5 and 6 can however be used in negotiations since new trucks are more energy efficient, draws less fuel.

5 Analysis

In order to investigate and give suggestions on how to measure the logistics performance of a construction supply chain, a conceptual framework was developed. The conceptual framework that is described in this section, focused on the process for the development of a logistics PMS.

The conceptual framework that was created can be seen in figure 5.1. The framework consists of four steps and should be applicable to most industries and companies, since a large focus of the framework is to analyze and evaluate the company, industry and supply chain characteristics. The framework is based on a combination of literature recommendations, regarding what to consider and to include while developing a logistics PMS. It should be viewed as a part of the research approach but also as a part of the output of this master thesis, which is here broken down into a step-by-step process. These steps are:

1. Business context and supply chain processes
2. Supply Chain Strategy
3. Design of KPI Scorecard
4. Identification and development of KPIs

The following sections will be structured in the same way as the conceptual framework. Each step and its purpose will be described, but also how it could be used for a company in the construction industry, e.g. for the case company Inköp AB.

5.1 Business context and supply chain processes

The first step when designing a logistics PMS is to analyze and evaluate the context and processes of the business and its supply chain, see figure 5.2. From the business context it is possible to create an understanding of what the business looks like, in what type of context the company operates in and what is required for it. Furthermore, as stated by Lohman et al. (2004) it is important to understand each functional area's role in achieving various objectives and how these are measured. In this case, it means to understand the construction supply chain and the strategic areas concerning logistics. This type of analysis provides the basis for identifying the relevant performance dimensions in a logistics PMS, but also provides the link to the overall company and supply chain objectives. Various authors have indicated

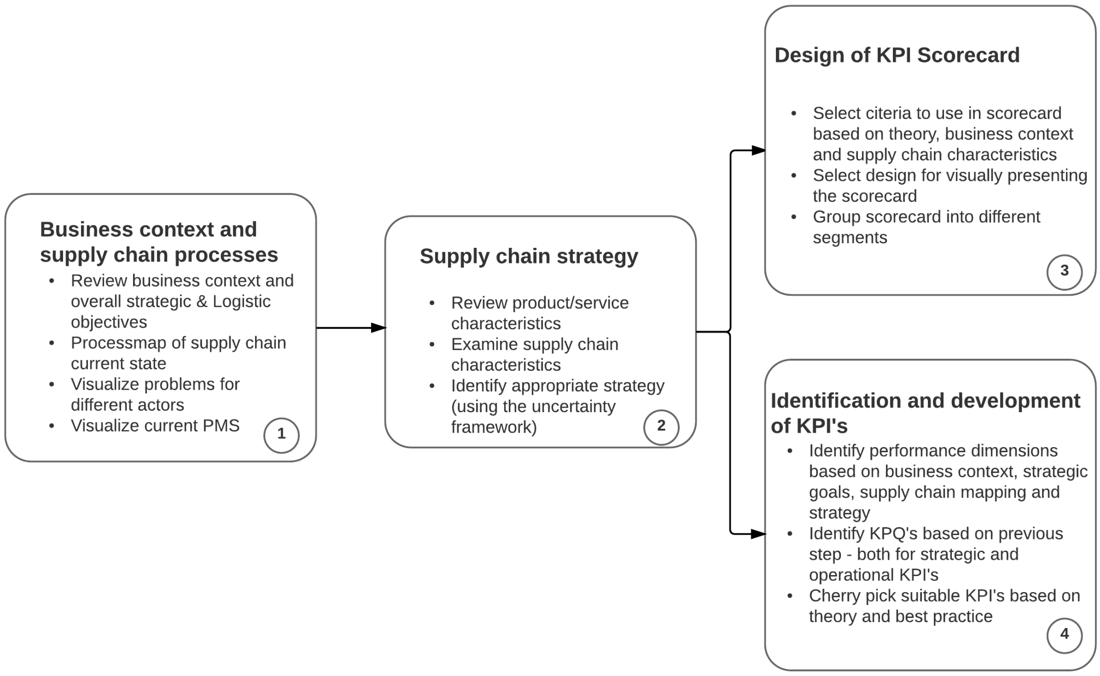


Figure 5.1: Conceptual Framework - Design of logistics PMS

the importance of linking the PMS and its KPIs to the strategic objectives and business context (Neely et al., 2000; Lohman et al., 2004; Thunberg and Persson, 2014; Tonchia and Quagini, 2010; Bourne et al., 2000; Marr, 2015). Marr (2015) further states that doing so gives the company valuable and relevant information that is required for monitoring the progress towards the strategic objective. In order to design a logistics PMS based on a holistic supply chain perspective, a construction supply chain was mapped which was suggested both in POA by Chan and Qi (2003) and in the SCOR model by Bolstorff and Rosenbaum (2012). Furthermore, a process orientation is important in order to enable continuous improvement. The combination of business context and supply chain process analysis does not only enable of a breakdown the objectives into each process step, but also helps identify the relevant performance dimensions to be included into the PMS. This should serve as a base for the identification of top level or strategic KPIs for the PMS. In addition, it should also help for the breakdown into operational KPI, thereby ensuring specificity.

5.1.1 Business context of a construction company

In the business plan for Bygg AB, it is stated that the overall purpose is to achieve *"profit with purpose"*, where purchasing has a great impact on the profit. The ambition is therefore for Inköp AB to become a world class purchasing department. This also means to keep a cost efficient purchasing function which is stated as an overall goal. Looking at the construction industry in general, this should be deemed as a prioritized target. As mentioned by Fernández-Solís (2008), there is a gap in terms of efficiency between manufacturing and construction industries. Inköp AB

Figure 5.2: First step in conceptual framework - business context and supply chain processes

contribute to the increased efficiency goal by sourcing certain product categories for a lower price through importing from low cost countries. This indicates that one of Inköp AB's competitive advantage is the price towards the customers. As mentioned in the empirical part, Inköp AB has confirmed with the customers that the initial reason for choosing Inköp AB is the price. However, in order to maintain the customers and the relationship, Inköp AB needs among other to perform well in both logistics and safety aspects. Furthermore, in the business plan of Inköp AB it is stated that the products shall to the largest extent be bought from suppliers that have the lowest total cost. However, the cost for freight and transportation is not included in the current KPI setup. Thereby it is hard for Inköp AB to follow up and make a fact-based decision when choosing supplier.

In order to retain a competitive price towards construction projects, the logistics have to be handled efficient. For industries such as manufacturing, it is mostly much easier to eliminate waste and be more efficient since the customers stay in the same location. As Azambuja and O'Brien (2009) mention, every project in the construction industry is unique and differs from earlier projects which also make each supply chain setup unique. In order for construction companies to be efficient in the logistics, volumes need to be consolidated. Thereby a profitable transport economy can be achieved, which directly influences the prices. One improvement area that was stated in the business plan of Inköp AB was to investigate how to consolidate volumes in a different way. Thereby it should be possible to increase tonnage as well as efficiency. This is also included as one of the objectives against 2020 as one of the supply chain strategic areas. That objective is stated as follows:

- Have an average weight of at least 20 tonnes per truck, for trucks with the maximum capacity of 24 ton (83 % fill rate)

Here it is important to consider the physical characteristics of the products that will be distributed in a construction supply chain. The product category reinforcement stands for the major turnover in Inköp AB and here the strategy is to increase the product group of prefabricated solutions. As stated in the empirical part, this will affect the transport efficiency negatively since the physical characteristics makes it hard to consolidate volumes. Thus, product strategies should be considered when designing a logistics PMS. For example, the targets of the individual KPIs needs to be differentiated depending on the intended strategy.

Inköp AB is currently measuring the transportation efficiency through the KPI fill rate. Although, this is not reported towards the management or board in a standardized and consequent way. Not having a standardized process for reporting could result in no actions taken to improve the situation of the logistics. Hence, this is not aligned with the thought of being able to follow up strategic objectives and company performance, as stated by several authors (Neely et al., 2000; Lohman et al., 2004; Thunberg and Persson, 2014; Tonchia and Quagini, 2010; Bourne et al., 2000; Marr, 2015). This is probably one of the reasons why the transports haven't been economically justifiable in the past for Inköp AB.

The deliveries towards a construction project site has to be of high quality and reliability to not cause expensive delays. In this case, Inköp AB have a great responsibility towards Bygg AB's projects. As mentioned by Jang et al. (2003) incomplete deliveries have a large impact on the construction industry, potentially affecting the upcoming production with delays and quality issues. This is also confirmed by Inköp AB's customers who expect reliable deliveries, reliable suppliers and good quality. These customer demands can be deemed as valid for the whole construction industry based on the importance of qualitative deliveries. Furthermore, it is also important to consider that the project sites often have issues regarding the space availability on site (Ekeskär and Rudberg, 2016). Fernández-Solís (2008) also highlight that the project site will be exposed to weather and specific site conditions which could affect the quality of the material. Hence, the timing of the delivery is crucial, and the deliveries should be neither to late or early. What is deemed as the perfect timing should be set by the customer. This subject is included in Inköp AB's business plan as one of the objectives against 2020 as;

- Achieve a delivery precision of 99 %

A common indicator for many companies is delivery performance, measured in terms of time. This can also be seen for the construction company Inköp AB, which uses this measurement to follow up the strategic objective delivery precision. Furthermore, the individual KPI quality, in terms of correct product quality, is also measured but is not directly connected to any objective. As mentioned by several authors Neely et al. (2000); Lohman et al. (2004); Thunberg and Persson (2014); Tonchia and Quagini (2010); Bourne et al. (2000); Marr (2015), it is critical to connect the KPIs towards the strategic objectives and vice versa. However, as mentioned by Thunberg and Persson (2014) less than 40 % of deliveries in the construction supply chain are delivered in full, meaning right amount, right time and location, damage free and right documentation. This concludes that construction supply chains generally have an issue with reliability. This gives an indication that these kind of aspects are not measured at companies in the construction industry and should be included in a logistics PMS. For this reason, it is suggested to include supply chain reliability as a dimension when designing a logistics PMS for construction supply chains.

Since Inköp AB has the goal to increase the product variety and volumes, this also necessitates a broader supplier base. Managing more suppliers puts greater attention on the possibility to compare different suppliers and their performance. Inköp AB has stated the following objectives in its business plan regarding management of suppliers.

- Establish structured way of working with supplier development to increase performance in quality and delivery
- Reduce risk of delays from manufactures. For some suppliers there must exist routines/procedures how to handle/avoid delays

As it has been concluded before, suppliers early in the construction supply chain have a huge impact on the performance of the construction projects, which also stated by Ekeskär and Rudberg (2016). Being able to compare supplier performance is something that should be considered as an application area for the future logistics PMS since it would allow for a more fact-based decisions when selecting and managing suppliers for any construction companies.

One of the strategic objectives of Bygg AB, is to create sustainability in the supplier base. These sustainability objectives have influenced Inköp AB to consider how it should be included in the business plan, and thereby how it should be measured. Ortiz et al. (2009) claims that the construction industry should proactively create environmental, social, and economic indicators which promote sustainable construction practices. The reason for this is that governments are suggested to apply certain construction codes and environmental policies in order to improve the sustainability in construction. Customers to construction companies like Inköp AB should therefore prioritize and expect a sustainable supply chain. Often the ability to respond to customer demands in the public sector is extremely important for construction supply chains, since it corresponds with a large market share.

5.1.2 Processes of a construction supply chain

As mentioned by Azambuja and O'Brien (2009); Karim et al. (2006) the relationship with the subcontractors and suppliers in construction supply chains, is of utmost importance since much of the work is performed by them. Since Inköp AB serve as an consolidation point between the projects and the material suppliers, Inköp AB needs to communicate the estimated project purchase order in adequate time so that the material supplier can produce. This is also considered to be one of the issues for construction supply chains, where Azambuja and O'Brien (2009) claims that the information flows are slow, and often involve lack of sharing of information across firms. As mentioned in the empirical part, the construction projects ordering pattern is varying. According Dörnhöfer et al. (2016), monitoring of information process should be perceived as important as the material flow. The importance of information processes is rising, e.g. with shorter customer ordering lead times. Thus, in order to understand the customer ordering pattern better and to make it more even, it should be measured and communicated between the actors in a construction supply chain. Furthermore, the ordering lead time is important to consider, but also the amount of orders. This could be used in order to understand the capacity constraint and create the possibility for forecasting. This would facilitate an aligned supply chain but also increase the responsiveness towards the customers. Traditionally, the lack of information sharing within the construction industry has been a reason to why construction supply chains are considered to be fragmented (Azambuja and O'Brien, 2009; Karim et al., 2006).

One of the main issues in the supply chain of Inköp AB, has been the process between the material supplier and the 3PL, and then the deliveries towards the project site. This has been expressed by late deliveries, damaged products or unsafe loading caused by incorrect loading. Inköp AB has in its business plan identified this as a strategy for the way forward.

- Closer cooperation with manufacturer regarding material loading plan and truck amount. Continuous dialog with projects and suppliers concerning circumstances of delivery and needs.

However, when a claim from a construction project appears, it is generally difficult to find out who and what the reasons were for the fault. The reason for this is often that there is a lack of KPIs, thereby not continuously measuring performance in the supply chain. Thereby it is also hard to identify what precautions should be made to prevent something similar to happen again, as well as managing the communication with the stakeholders. This is another example of what Ekeskär and Rudberg (2016) conclude, that many of the issues have their origin upstream in the supply chain but their effects propagate to the construction site. Expectations and demands on one actor should also be communicated to the other actors in order to get an aligned supply chain. This should be done with a clear structure, so that all actors know which part is responsible for what. Another important thing might be to inform the other actors in a supply chain what the actual impact of a claim is, thereby creating an understanding of why the project site is focused on prohibiting it. In the case of Inköp AB, it has been stated that no targets for any types of KPIs have been negotiated in the framework agreement. This means that Inköp AB only measures by themselves, and that the 3PL does not have to fulfill certain KPI targets in order to fulfill the contract. Thus one should have several measurement points earlier in the supply chain to prevent any inaccuracies in an early stage. This is also confirmed by Lohman et al. (2004) who states that in order to understand the causes of deviations of actual performances, each measure should be able to be drilled down to different measures and levels of detail. Although, it is important that the measurements define and measure the performance of the supply chain as a whole.

5.2 Supply chain strategy

The second step when designing a logistics PMS, is to identify and analyze the supply chain strategy, see figure 5.3. By analyzing and understanding a company's supply chain, it is possible to identify the appropriate type of strategy to use. In order to tackle the different challenges in a supply chain, Chopra and Meindl (2016) highlight the importance of aligning the company's context and objectives to the supply chain strategy. Understanding what type of supply chain the company is operating in should benefit the entire organization, thereby facilitating the findings of an approach towards a more suitable strategy. Furthermore Lee (2002) states that a company should prepare and adapt their supply chain strategy to their context, since one-size-fits-all mentality will fail. As mentioned by Lee (2002) and Chopra and Meindl (2016), the strategy should clarify what the most important factors for the supply chain are, thereby ensuring focus on the right aspects. In this master thesis, it is important to understand what those factors are, since this is essential to consider when designing a logistics PMS. Thus, the appropriate KPIs can be selected that are aligned with the supply chain strategy. Furthermore, according to Lohman et al. (2004) the measurements should define and measure the performance of the supply chain as a whole. The identification of the strategy should emphasize the view of companies within the supply chain as a collective entity rather than independent units.

Regarding the supply chain strategy at Inköp AB, there is no outspoken strategy for it. In order to identify the most appropriate supply chain strategy for a construction supply chain, the uncertainty framework developed by Fisher (1997) and Lee (2002) was used. Doing so meant first analyzing the demand characteristics of the product or services of the company, dividing in two main categories: functional products and innovative products. Secondly, the supply characteristics were analyzed, which also was divided into two groups; stable- and evolving supply. The red circles in figure 5.4 and 5.5 show the evaluation of both demand and supply characteristics.

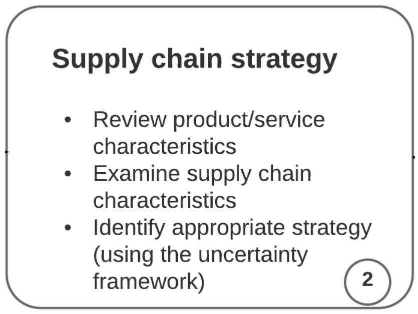


Figure 5.3: Second step in conceptual framework - supply chain strategy

In the following sections, the previous mentioned uncertainty framework will be adapted to the construction industry, thereby trying to identify the most suitable supply chain strategy for construction supply chains. In order to do so, the demand characteristics and supply characteristics for the construction industry will be examined. However, the uncertainty framework is commonly used for a specific type of product group, and is not easily applied for a general concept like the construction industry. Since construction supply chains are part of such a broad field, it might be difficult to both generalize and determine the exact location of the demand- and supply characteristics in the framework. However, in order to adapt this concept as good as possible, the case company in this research was examined and compared to theoretical findings from the general construction industry. Thereby, the analysis of the demand characteristics are for the case company based on a product group, reinforcement. Reinforcement stands for most of the turnover in the case company that was examined, thereby being considered as a good comparison to use when applying it to the examination and analysis of demand characteristics.

5.2.1 Demand characteristics for construction supply chains

When evaluating the context of the case company, the demand characteristics for reinforcement could be considered to have high demand uncertainty, be difficult to forecast, and to have a variable demand. These three product characteristics could be explained by claiming that the material and trade flows can be seen as more complex, thereby leading to higher variability (Azambuja and O'Brien, 2009). Furthermore, since a project never is entirely the same, every single order from project site to supplier will be different. This means that the demand uncertainty and variability might be high, as well as making the forecasting more difficult.

However, looking at the construction industry in general, products should instead be considered to have low demand uncertainty and have a more predictable and stable demand. This is a clear distinction towards what was seen in the case company. The reason for this was that large companies in the construction industry in general can be considered to have large order volumes, whereas the customers have to order well in advance in order to ensure that the goods are delivered just-in-time. This is also stated by Azambuja and O'Brien (2009), who claim that the product demand in the construction industry is less uncertain due to that the amount of material is normally known in some time before. This is not the case for Inköp AB, where interviewees stated that customers often order too late and with a varying customer ordering lead time, thereby creating difficulties in forecasting.

Another aspect that was examined in the context of the case company and the construction industry in general was the inventory cost. The inventory cost was deemed to be high for the case company, which generally also is the case for the construction industry where the space availability on the project sites is low (Azambuja and O'Brien, 2009). This means that the delivered volumes take a lot of space that could be used for another purpose. At the same time, the stock-out cost can be considered to be high as well, since the project are heavily reliant of the reinforcement to be at site on time. If they are not, this mostly means a large delay in costs for the project as concluded by Jang et al. (2003), and thereby indirectly for Inköp AB who is responsible for the goods to be on site.

For the case company, the product group reinforcement have the demand characteristics of having a very long life cycle. This is similar to the whole construction industry, since the products are mostly included in buildings which are supposed to last for a lifetime at minimum. Furthermore, a majority of the reinforcement products are deemed to be quite easily produced. Although, the prefabricated solutions contain a lot of specifications which make them harder to produce.

The products that are sourced from the case company are mostly considered as quite easy to produce, something that can be observed for general construction companies as well. Another demand characteristic of products in construction supply chains is that the product variety in general is pretty low. This does not mean that there are few types of products that can be sourced. Instead it refers to the fact that most products are pretty standard, but can be modified if the customers wish for it. Something similar can be seen in the case company Inköp AB, where the product variety that is offered for reinforcement is low. In total five different product types of reinforcement are provided, which are available for customization in some degree. Another characteristic of reinforcement is that they have a very high volume per unit and order. For construction supply chains it is difficult to generalize this aspect since every product is different. However, most products that are sourced from construction projects are bulky and require a lot of space, and should therefore be considered to have the product characteristics "higher volumes per SKU", see figure 5.4. Lastly, the defects in relation to the total ordered quantity per year is considered low for both the construction industry and the case company Inköp AB.

In figure 5.4 there are in total eight of ten demand characteristics for construction supply chains that were deemed to be classified as functional products. Due to this, it should be clear that the demand characteristics in construction supply chains are mostly considered to include functional products. The general description of functional products is that they are products which aim to satisfy basic needs of customers, with stable demand. Innovative products on the other hand are products which are considered to be volatile, with a short life cycles. These definitions also goes along with the decision to view construction supply chains as functional products.

5.2.2 Supply characteristics of a construction company

As can be seen in figure 5.5, almost all of the ten supply characteristics for construction supply chains are considered to be part of a stable supply process, thereby indicating that the general supply uncertainty in construction supply chains should be considered as low.

One example of such a supply chain is seen in the case company Inköp AB. There, the company has a quite unchangeable supplier base and thereby has a good relationship with each of these. Furthermore, since Inköp AB has in total twelve suppliers to

Functional products	Innovative products
Low demand uncertainties	High demand uncertainty
More predictable demand	Difficult to forecast
Stable demand	Variable demand
Long product life cycle	Short selling season
Low inventory cost	High inventory cost
Low profit margins	High profit margins
Low product variety	High product variety
Higher volumes per SKU	Low volumes per SKU
Low stockout cost	High stockout cost
Low obsolence	High obsolence

Figure 5.4: Demand characteristics for construction supply chains

source from, there are several options if there should be an unscheduled breakdown, hereby leading to less capacity constraint. This is something that can also be seen for the entire construction industry, whereas companies have the possibility to source from various suppliers, since the products are mostly very common. However, one characteristic that could be deemed as an evolving supply process characteristic is the difficulties to changeover. This refers to the challenges that appear when a change of an order occurs during production or when an order is mediated. Since the sourcing is generally made in large quantities and often need to be transported a long way, it could be argued that this characteristics is considered difficult to changeover. In total, the supply characteristics for construction supply chains should be considered to have a stable supply process, meaning that the supply uncertainty is low.

Stable Supply Process	Evolving Supply Process
Less breakdowns	Vulnerable to breakdowns
Stable and higher yields	Variable and lower yields
Less quality problems	Potential quality problems
More supply sources	Limited supply sources
Reliable suppliers	Unreliable suppliers
Less process changes	More process changes
Less capacity constraint	Potential capacity constrained
Easier to changeover	Difficult to changeover
Flexible	Inflexible
Dependable lead time	Variable lead time

Figure 5.5: Supply characteristics for construction supply chains

5.2.3 Uncertainty framework for a construction supply chain

From the analysis that was presented in the two previous sections (demand and supply characteristics of construction supply chains), it is possible to map where a company's supply chain is located in the uncertainty framework that was developed by Fisher (1997). This framework can be seen in figure 5.6. The main purpose of this framework according to Fisher (1997) is to help the company to understand how the supply chain should be structured and what strategy to use in order to satisfy the demand of the products. In this master thesis, this gives an indication for which performance dimensions that should be included in the logistics PMS of construction supply chains. Moreover, it thereby also facilitates the process of developing KPIs that are included in the logistics PMS. Doing so should help align the supply chain strategy with the logistics PMS of the supply chain.

According to Lee (2002), a company should aim to reduce both types of uncertainties described in the uncertainty framework. This means that a company should ideally try to move into the top left box of figure 5.6. Based on the analysis of the previous sections, construction supply chains are located in the upper left corner in figure 5.6. That would mean that they would be classified as efficient supply chains, with the characteristics of functional products and stable supply processes. Relying on the stated analysis would mean to recommend construction supply chains to be more efficient. This would mean to constantly aim for creating a cost efficient structure, pursuing economies of scale and to deploy optimization techniques in order to achieve a high capacity utilization in production and distribution (Lee, 2002). This can also be compared and aligned with the strategies and objectives that were stated in the business plan of the case company that was examined for this master thesis. Even though the case company did not have the exact same characteristics as construction supply chains, it would still be suggested to use an efficient supply chain strategy.

Although it was concluded that construction supply chains had demand characteristics that were matching the characteristics of functional products, there was also a part of the characteristics that were deemed as innovative products. Thereby, an arrow in figure 5.6 indicates that construction supply chains might also in some cases lean towards a responsive supply chain. According to Lee (2002), this indicates that build-to-order processes and mass customization are means to use in order for the company to meet requirements from the customer. This is also consistent with the product group reinforcement that is provided by Inköp AB, where some degree of customization and large order quantities are used. Based on the reasoning that companies should be located in the upper left corner, Lee (2002) suggest to reduce the demand uncertainty in order to reach there. Moreover, there should be an increase in information sharing or closer collaboration in the supply chain to achieve this. Information sharing and closer collaboration should be facilitated when introducing a logistics PMS in a supply chain. From this analysis it can be concluded that the logistics PMS of construction supply chains should mainly cover efficiency, but also responsiveness in its performance dimensions.

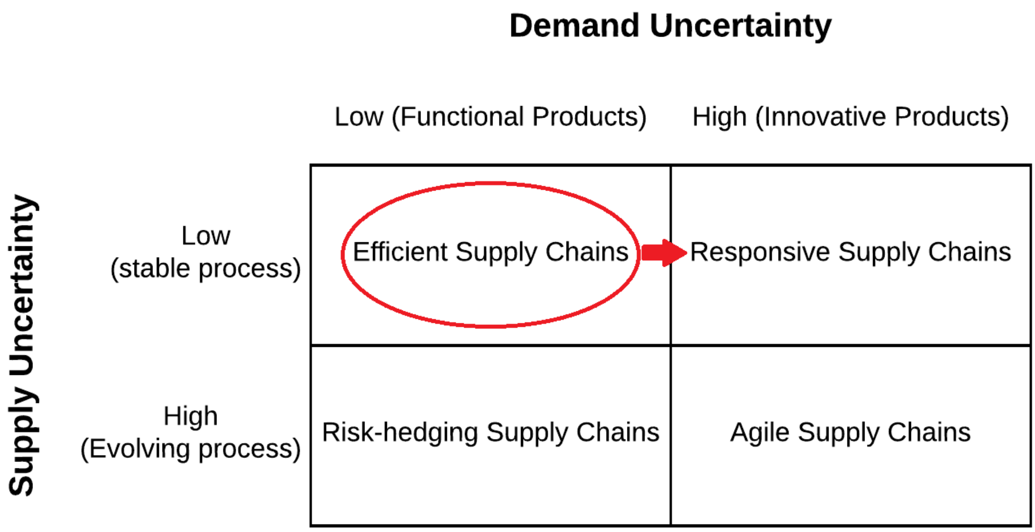


Figure 5.6: Position of construction supply chains in the Uncertainty Framework

5.3 Design of KPI scorecard

The third step when designing a logistics PMS, is to design how the elements or KPIs of the PMS should be presented. As mentioned by Lohman et al. (2004) and Marr (2015), it is important to have an appropriate design for the way the performance data will be presented, meaning some kind of design template or KPI scorecard. Doing so helps eradicating the ambiguity, ambivalence, and inconsistency that might otherwise be an issue when collecting data for KPIs. In this master thesis, a template was created for what a "KPI scorecard" should include, based on Lohman et al. (2004) and Marr (2015) recommendations and empirical findings, see figure 5.8.

According to Bourne et al. (2000), the design of a PMS mainly is about identifying key objectives and designing measures. Objectives of the scorecard for each metric is to ensure the same application of the KPIs throughout the company and supply chain. In addition, the transparency of data sources, the calculation and the interaction of other KPIs should be targeted as well. Furthermore, having such a KPI scorecard should help define what the KPI measures, how to collect the data, and all around just explain what and how it is fitted into the PMS of the supply chain. For this reason, all of the selected KPIs in this master thesis were designed with the same template. In that way it was ensured that all the KPIs had the same categories and that they had an aligned output in some degree.

When choosing the design or template of the KPIs that are the foundation for a logistics PMS, one aspect is to group the scorecard into different categories of a scorecard. This means for example having one part of the template describing general and basic information, another part that covers more technical aspects, and having a third part that presents the strategic categories as mentioned by (Marr, 2015; Lohman et al., 2004). The same approach was chosen for the scorecards of this master thesis, where the different parts are:

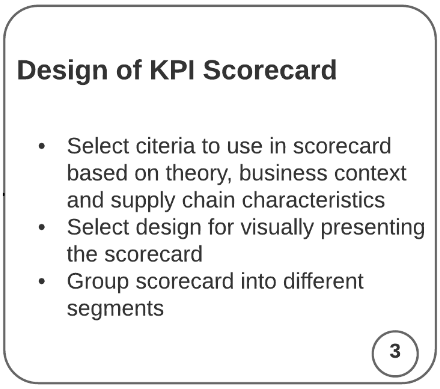


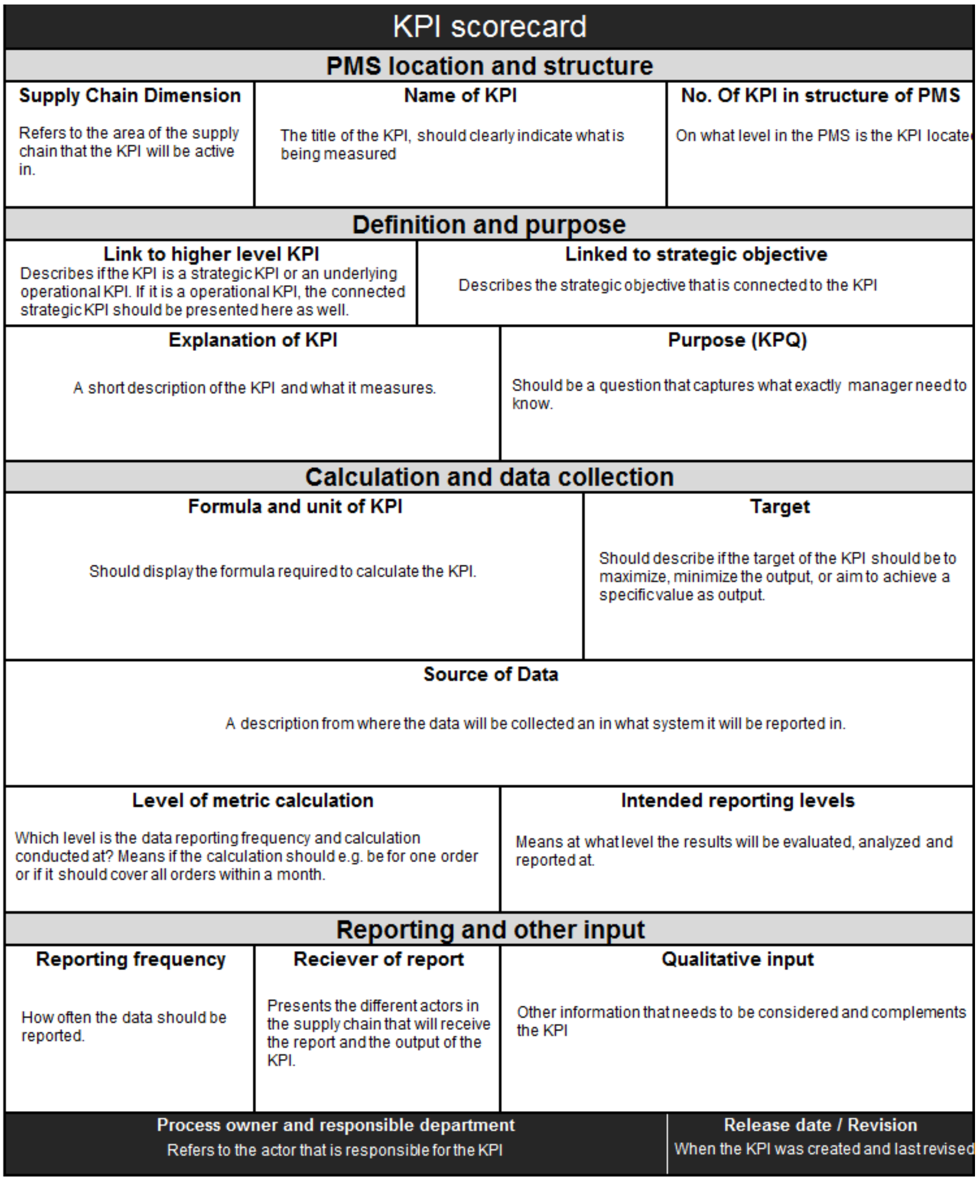
Figure 5.7: Third step of conceptual framework - Design KPI Scorecard

- PMS location and structure - Where the KPI is located in the logistics PMS and what supply chain dimension it relates to.
- Definition and purpose - The explanation and definition of the KPI but also the purpose or the KPQ.
- Calculation and data collection - How the KPI should be calculated and assessed but also what is the source of the data. Where the data has it origins should be specified in order to assure its reliability and validity (Marr, 2015; Lohman et al., 2004).
- Reporting and other input - How often the KPI should be reported and to whom. Also what other qualitative data are there that complements the KPI.

5.4 Identification and development of KPIs

The fourth and final step in the conceptual framework when designing a logistics PMS, is to identify and developing suitable KPIs. From this perspective, the case company will be examined, thereby facilitating information on which KPIs to select when handling construction supply chains. The logistics PMS is the three different levels as recommended by Neely et al. (2000) and Tonchia and Quagini (2010). The three levels are elements, architecture, and interface.

The first level of the PMS is the elements or the KPIs. Tonchia and Quagini (2010) differ between strategic, tactical or operational which is the first feature of the second level, architecture. The proposed logistics PMS for companies in the construction industry consists of 6 strategic KPIs. These strategic KPIs contains underlying, operational KPIs, which should be seen as necessary in order to analyze the output of the strategic KPIs that have been selected. This master thesis aimed to follow the advice given by senior lecturer Ola Hultkranz from Chalmers University (Lecture on performance measurement, 28th September 2015), who recommended to apply 5+/-2 KPIs since people only can retain 3 to 7 concepts in short-term memory. This can be aligned with the views of Gordon (2008), who states that one should not measure too many things at once. Instead, one should be focusing on only



KPI scorecard

PMS location and structure

Supply Chain Dimension
Refers to the area of the supply chain that the KPI will be active in.

Name of KPI
The title of the KPI, should clearly indicate what is being measured

No. Of KPI in structure of PMS
On what level in the PMS is the KPI locate

Definition and purpose

Link to higher level KPI
Describes if the KPI is a strategic KPI or an underlying operational KPI. If it is a operational KPI, the connected strategic KPI should be presented here as well.

Linked to strategic objective
Describes the strategic objective that is connected to the KPI

Explanation of KPI
A short description of the KPI and what it measures.

Purpose (KPQ)
Should be a question that captures what exactly manager need to know.

Calculation and data collection

Formula and unit of KPI
Should display the formula required to calculate the KPI.

Target
Should describe if the target of the KPI should be to maximize, minimize the output, or aim to achieve a specific value as output.

Source of Data
A description from where the data will be collected an in what system it will be reported in.

Level of metric calculation
Which level is the data reporting frequency and calculation conducted at? Means if the calculation should e.g. be for one order or if it should cover all orders within a month.

Intended reporting levels
Means at what level the results will be evaluated, analyzed and reported at.

Reporting and other input

Reporting frequency
How often the data should be reported.

Reciever of report
Presents the different actors in the supply chain that will receive the report and the output of the KPI.

Qualitative input
Other information that needs to be considered and complements the KPI

Process owner and responsible department
Refers to the actor that is responsible for the KPI

Release date / Revision
When the KPI was created and last revised

Figure 5.8: Suggested KPI template with explanations

measuring a number, thereby still making it possible to manage them. The second feature in the architecture level refers to what part of the organization the PMS belongs, which in this case is the logistics of the case company that was examined. The last feature in the architecture level refers to the different dimensions in which the PMS is structured. In the case of a construction company like Inköp AB, the dimensions are structured according to four different supply chain dimensions such as; reliability, efficiency, responsiveness and sustainability, as can be seen in figure 5.10. These dimensions are based on the analysis and reasoning made in the section 5.1 and 5.3, which originates from literature and empirical findings.

The last level is the interface of the PMS. According Neely et al. (2000) and Tonchia and Quagini (2010), this is how the PMS is integrated with the organization. This is covered by describing each KPI in the report. In general, each KPI is described with

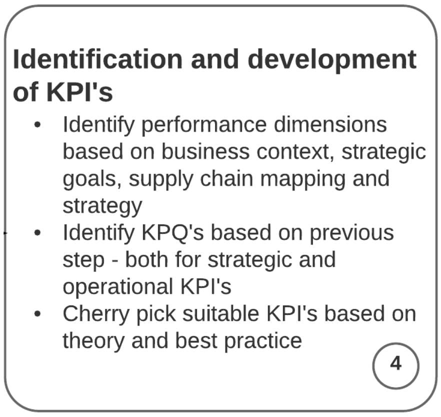


Figure 5.9: Fourth step of conceptual framework - Identification and development of KPIs

the same structure. Each KPI will first cover the purpose, among others presenting the strategic objectives connected to the KPI and what KPQ that was stated. Next the definition of the KPI will be discussed. Here the meaning will be described in-depth, going through what is measured and what should be the target for the KPI. Lastly, a section describing the practicalities that are required when implementing the KPI in the organization.

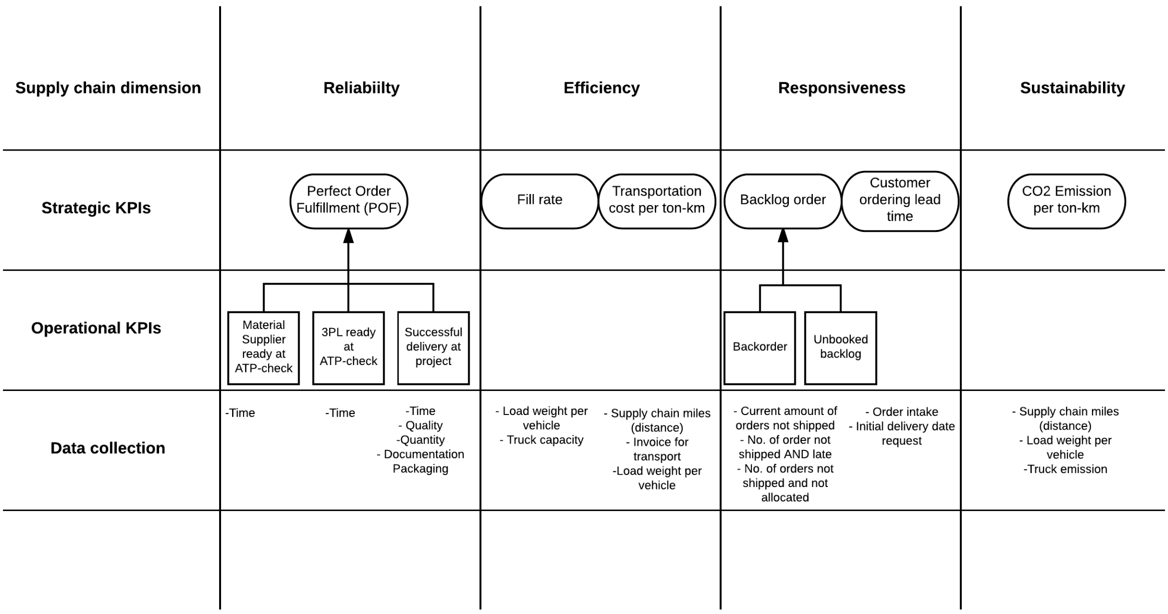


Figure 5.10: Overview of suggested logistics PMS

5.4.1 Reliability

Reliability can be seen as the ability of one specific event or activity to perform a required function under stated conditions for a stated period of time (Chan and

Qi, 2003). As mentioned in section 5.1, reliability of the deliveries for Inköp AB is of highest importance due to the effects of incomplete deliveries at project sites within the construction industry. For this reason, supply chain reliability was chosen as one of the dimensions for the logistics PMS. According to Bolstorff and Rosenbaum (2012), measuring reliability in a supply chain starts with the deliveries, which should fulfill the following criteria: correct product, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, and to the correct customer. In order to cover these aspects, perfect order fulfillment was suggested as a KPI.

Perfect Order Fulfillment

In order to select a KPI that was able to secure supply chain reliability, the concept of perfect order fulfillment was examined. This meant developing a KPI that should measure how many of the orders received that are carried out perfectly. This KPI was "cherry-picked" from literature and then validated through empirical findings. For that reason it was deemed to be a strategic KPI, and was suggested to have three operational KPIs that should provide necessary information in order to calculate the POF. The three underlying KPIs that should be connected to the POF should be:

- **Material supplier ready at available-to-promise (ATP-) check** - Meaning that the supplier is prepared for the loading of the trucks on the right date and time, see appendix C.1.
- **3PL ready at ATP-check** - Referring to if the trucks ordered from the 3PL are present at the agreed date and time, see appendix C.2.
- **Successful delivery at project** - Refers to if the project receive the goods in accordance to various crietria. This means that the projects need to be measured according to that the delivery is on time, the right packaging, correct quality and quantity, and right documentation has been delivered, see appendix C.3.

Introducing the Perfect Order Fulfillment as a KPI in a PMS should aim to answer the KPQ; *Where, what and why is there an issue causing an incomplete order towards the project?*. Answering this KPQ is essential for two reasons. First of all, measuring some kind of delivery performance towards the customer is an advantage for any supply chain, since it clearly indicates where problems are and what the reasons for the problems have been. In the case of Inköp AB, this is done by measuring if the order is delivered on time towards the project at Bygg AB. Secondly, as mentioned in the discussions with the reference group and by Lohman et al. (2004), being able to have an strategic KPI which can be broken down into several operational KPIs is be extremely valuable. Almost all of the interviewees in the reference group liked Perfect order fulfillment, since it covers such a large amount of information and involves many aspects. The operational KPIs should measure the output earlier in the supply chain. Thereby, one can be more proactively in the decision-making in order to improve the delivery performance towards the customer.

In the case of Inköp AB, it should support e.g. a claim process with a customer by visibly showing where something went wrong and who is responsible.

Perfect order fulfillment can be be explained as the average % of perfect orders towards projects during a time period. If anything in the order is not done correctly, according to stated operational KPIs or by not fulfilling criteria, the order should get a 0 % POF. On the other hand, if the order is considered to be perfect, it should get a 100 % POF. As stated before, the strategic KPI (perfect order fulfillment) should be able to be broken down into the above presented operational KPIs, which take into account several criteria. These criteria are:

- **Time** - which measures and makes sure that the transports are not late and not early. The transports should arrive on the exact date and time that was confirmed by all actors. A small buffer should be included, allowing the transports to have a window of time to arrive either a short time before or later. As described by Azambuja and O'Brien (2009), since the project sites are lacking standardization, they often have problems with no space availability at the sites. This is something that was confirmed for the customers of the case company as well. Thus, having deliveries on time is of high importance for construction supply chains.
- **Packaging of product** - Refers to measuring if the packaging and loading of the goods were done correctly. This criterion mainly originates from that there has been several claims from projects that have criticized this. Often, not loading and packaging the trucks in the correct way generates safety issues, or require extra time to unload.
- **Quality** - Should measure if the right product was delivered, and if the goods meet the technical requirements that was ordered, and have the right condition.
- **Quantity** - Refers to if the right amount of goods has been delivered to the customer. Not delivering the right amount of goods could have critical consequences for the customers, since this might create delays for the entire project.
- **Documentation** - Should measure if the right documentation is included when the goods are transported, thereby securing that the transport and delivery of the goods have been executed correctly.

Thereby it should be able for companies in the construction industry to identify certain patterns. This could for example mean finding that a big part of the problems in the supply chain come from quality faults, which the suppliers are responsible for. In the long run it should also be possible to divide the suppliers, and compare them within the different criteria.

As stated above, one criteria within the perfect order fulfillment was quality, which was initially planned as a strategic KPI in the case study of this thesis. However, as stated in the empirical data, it was decided that quality would not be a strategic KPI, but instead would be included as an underlying, operational KPI in the POF. Still keeping quality as an operational KPI is important for various reasons. The

KPI scorecard

PMS location and structure

Supply Chain Dimension	Name of KPI	No. Of KPI in structure of PMS
☑ Reliability ☐ Efficiency ☐ Responsiveness ☐ Sustainability	Perfect Order Fulfillment (POF)	*On what level in the PMS is the KPI located?* 1.1

Definition and purpose

Link to higher level KPI	Linked to strategic objective
☑ KPI is a top level indicator (Strategic KPI) ☐ Operational KPI and related to;	Business plan logistics; Achieve a 99 % delivery precision

Explanation of KPI	Purpose (KPQ)
Average % of perfect orders towards projects during a time period. If anything in the order is not done correctly, meaning not fulfilling critieria for operational KPIs 1.1.1 Material supplier ready at ATP check, 1.1.2 3PL ready at ATP check and 1.1.3 Sucessful delivery at project, the order gets a 0 % POF. If it is perfect for all operational KPI's, it gets a 100 % POF.	Where, what and why is there an issue causing an incomplete order towards the project?

Calculation and data collection

Formula and unit of KPI	Target
$\frac{\text{Amount of perfect orders}}{\text{Amount of orders}} \times 100$ = % of Perfect Orders	☐ Minimize ☑ Maximize ☐ Specific value;

Source of Data

☑ ERP System (Monitor) ☑ Survey ☐ Order tracking system	The Perfect Order Fulfillment depends on several operational KPI's, 1.1.1 Material supplier ready at ATP check, 1.1.2 3PL ready at ATP check and 1.1.3 Sucessful delivery at project. The data for these should be complied and gathered in the ERP system which automatically calculate the POF.

Level of metric calculation	Intended reporting levels
Which level is the data reporting frequency and calculation conducted at? ☐ Shipment (Per vechicle) ☑ Order ☐ Product Group	*On what level will the data be evaluated and analyzed?* ☐ Shipment (Per vechicle) ☐ Order ☑ Product Group ☑ Supplier ☑ Customer

Reporting and other input

Reporting frequency	Reciever of report	Qualitative input
How often is data evaluated and analyzed? ☐ Daily ☐ Weekly ☑ Monthly ☐ Other	☑ Operative team ☑ Company management ☑ Company board ☑ Suppliers ☑ 3PL ☑ Customer ☐ Other	*Other information that needs to be considered and complements the KPI* Observe that POF is affected equally by all measured criteria. Meaning for example that a documentation error has the same "importance" as not delivered in time.

Process owner and responsible department	Release date / Revision
Logistic operator at Inköp AB	XXXX-XX-XX

Figure 5.11: Perfect Order Fulfillment

most significant reason is that quality is a direct indicator on what performance the services or products have towards the customer. In the case of Inköp AB, this mostly means how well the reinforcement meet technical requirements made by the customer. In the case of Inköp AB, measuring quality makes it possible to compare the performance of different suppliers. Since quality holds such critical importance to the customer, it is necessary to improve the suppliers if they do not perform well enough in that aspect.

Another important point that was discussed thoroughly during the interviews was if it was possible to collect all the required data for calculating the POF. The plan for the case company Inköp AB was therefore that the three operational KPIs should collect the data by accessing the current order tracking system and by creating some sort of digital survey for the projects. This survey should require yes or no answers in regard to the fulfillment of the criteria discussed. Next, the data that was collected should be reported into the ERP-system of the supply chain, where it should be compiled and be available for the calculation of the POF.

In the case of Inköp AB, this KPI would be visible and reported to the Inköp AB's operative team, management and board. Since the KPI contains so many aspects and criteria, chances are that the output will not be very high. However, it should not matter exactly what the level is, instead the focus should lie in analyzing the problems in the supply chain and trying to improve those.

It should also be mentioned that POF is affected equally by all measured criteria. This means that for example a documentation error has the same "importance" as if the goods were not delivered in time, even though it should be clear that the latter would be much worse to the case company. Due to this, it is important that the company just tries to improve the results of the KPI just to look good, but actually still tries to evaluate and analyze which improvements actually give the largest effect on the supply chain.

5.4.2 Efficiency

One of the main aspects in industries such as manufacturing is the efficiency, which is associated with reducing costs and eliminating waste. As Fernández-Solís (2008) mention, the manufacturing industry is superior in efficiency in comparison to construction industry. The uncertainty framework in section 5.3 showed that in the case of Inköp AB, an efficient supply chain is most suitable. Furthermore, based on the importance of efficiency for Inköp AB in utilizing their transports as described in section 5.1, this is something that needs to be included as a dimension in a logistics PMS. In order to cover supply chain efficiency, the KPIs fill rate and transportation cost per ton-km were chosen, since they give a clear indication on how efficient the transports in the supply chain are.

Fill rate

Measuring the fill rate of a truck has a big influence on a supply chain like the one in the case company. As stated in the empricial data, Inköp AB currently buys Full Truck Loads (FTL), which means that they order the entire trailer from the 3PL and are themselves responsible for consolidating the transports. According to the reference group, fill rate is affected by both the environment and the cost in a supply chain. Including fill rate for the logistics PMS means trying to answer the KPQ *"How efficient are we when using truck capacity and consolidating orders?"*. In the case study that involved Inköp AB, the business plan therefore stated an strategic objective to have an average of 20 tonnes on each truck (equals 83 % fill rate). However, there is currently no automated data collection method. Instead, the fill rate is being measured manually from employees responsible for order management within Inköp AB. Furthermore, due to a previous mistake in the data collection, there is only historical data available from the last two quarters of 2016.

The definition of fill rate is the average used capacity on each truck, and should furthermore also be broken down per product group. This means that it should be possible for the board at Inköp AB to see the average fill rate, but to also have access to the underlying data where the different product groups can be compared to each other. Another important aspect to consider when implementing a KPI are the key drivers, which are the attributes that affect the outcome of the indicator. For fill rate, one key driver is the product characteristics, meaning the density that the products have and how difficult the products are to load. Other key drivers include the number of orders that the company receives, how much it is possible to consolidate different orders, and the capacity of the trucks. Fill rate should therefore also measured in what way the product groups differ in fill rate.

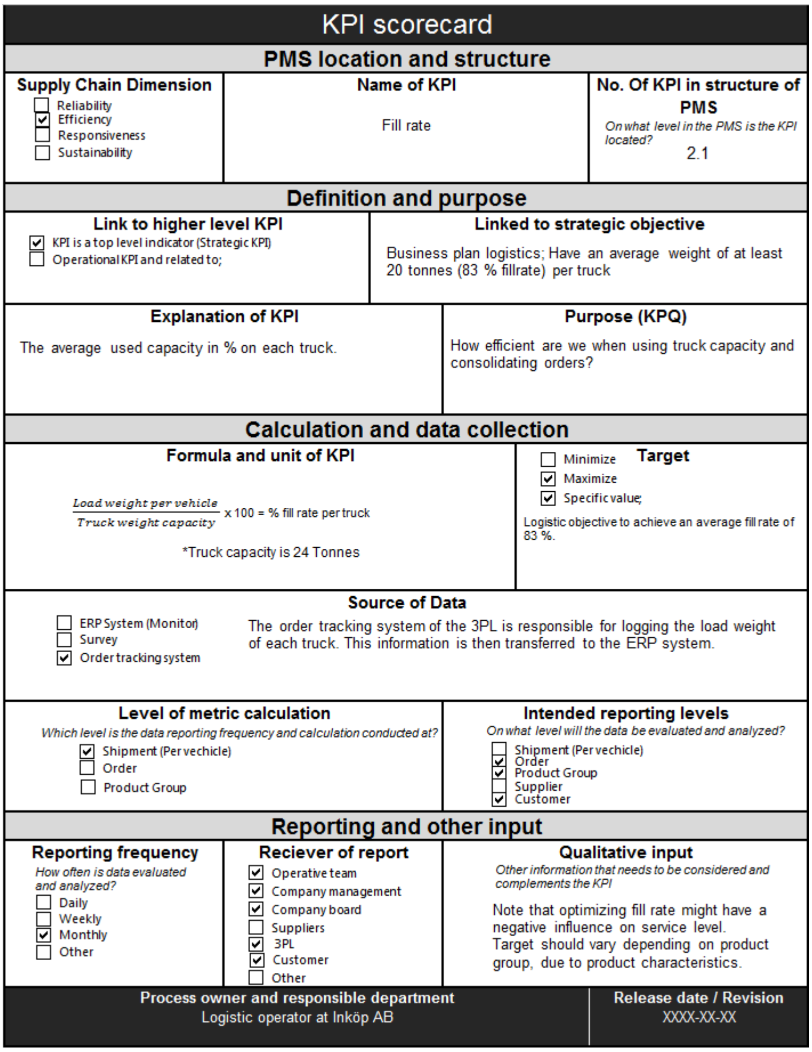


Figure 5.12: Fill rate

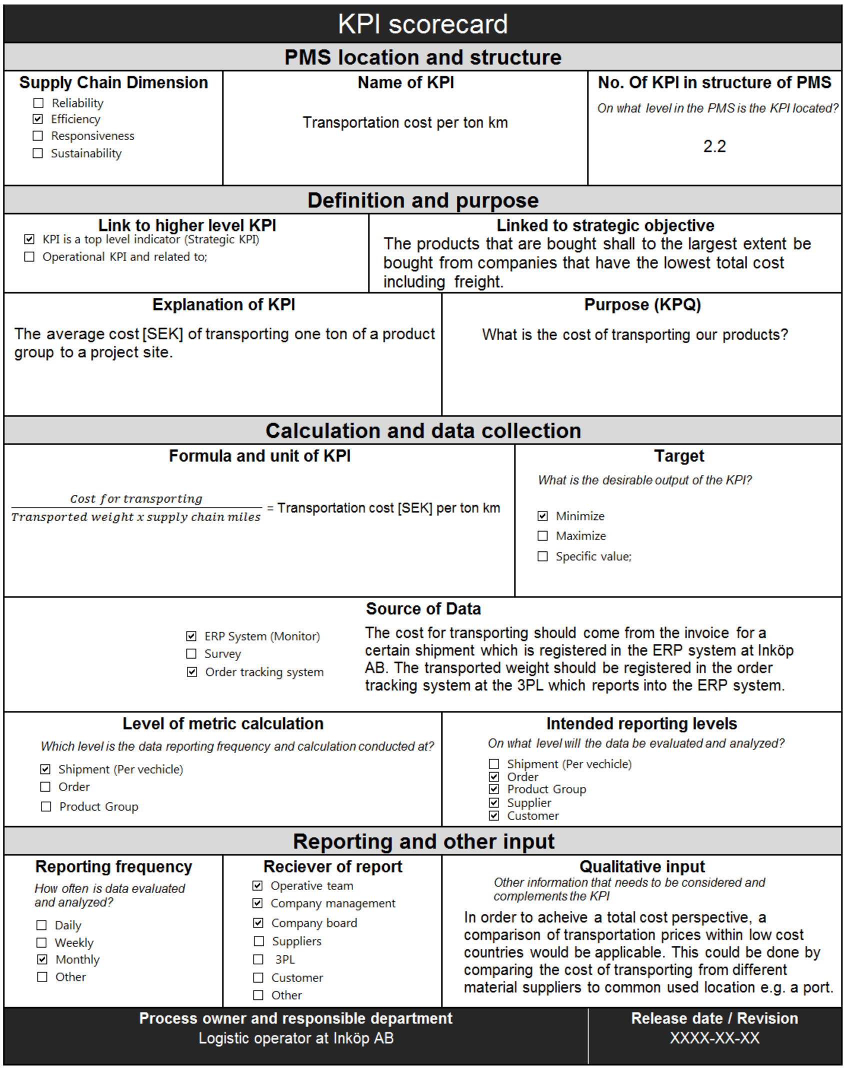
Fill rate should monthly be reported to the board, thereby creating an awareness to how economic the transports are, and how *"green"* the transports in the supply chain are. Fill rate can also be referred to as load factor, which Santén (2016) defines as the ratio of the load carried (required capacity) and the maximum load that could be carried (available capacity). The most important aspect however will be to secure a data collection method that continuously and automatically displays the monthly fill rates for the company. This means that the order data needs to exist in the order tracking system of the 3PL. The load weight of each truck should there the logged and later transferred into an ERP system.

In the discussions with the reference group, there was divided opinion whether one of the KPIs fill rate and transportation cost should be an operational KPI instead of a strategic KPI. However, both KPIs were at the end considered to be very important. It should be in the boards interest to report fill rate at a strategic perspective. For companies that source internationally, fill rate is even more important, since the transports have a longer way to go. This means that the cost of not achieving a high fill rate would be very high for a company like Inköp AB.

Another interesting point, which was also discussed during the interviews, was the optimization of fill rate. This does not in any ways mean that the companies should try to maximize the fill rate. Instead it is suggested that companies should analyze and evaluate historical data from both fill rate and transportation cost per ton, and try to find the most cost-effective way for the transportation. However, it must also be considered that a high fill rate in some cases comes at the risk of a trade-off with service level. In the the case of Inköp AB, service level is of high importance, thereby making it difficult to achieve a "too high" fill rate. Instead of compromising and possibly lowering the service level due to an effort to consolidate more, Inköp AB should instead try to use it as an incitement when project order. This means presenting to the customer that increasing the volume might achieve a better fill rate, thereby facilitating a better price for the transport.

Transportation cost per ton-km

Transportation cost per ton-km is a KPI that should measure the average transporting cost towards a project. However, the KPI should also measure per km and ton, in order to get an appropriate average of what it costs to transport the goods. If the KPI would not take the distance into account, every transport from far away would automatically be very expensive, thereby making the comparison between various customers and suppliers very difficult. The weight should also be included, since the transportation cost of the 3PL will increase if the load weight is higher. Moreover, it is very relevant to see how the cost varies depending on what product group was transported, and which the achieved fill rate was for each transport. One suggestion that was made during one of the interviews was to only use fill rate as a KPI, and having an analyst that would summarize the data for this KPI once a year. However, this was not deemed to be suitable for this thesis, where it instead was concluded that it would be advantageous to continuously measure the transportation cost per ton-km. When transportation efficiency is of highest importance, such as the case of Inköp AB, it should be more continuously followed up. Doing so should make it possible to make a comparison with fill rate, and help analyzing how the fill rate affects the transportation cost per ton-km. Another applicable area of use would be for the purchasing and sales departments within Inköp AB, where customers should be convinced of the advantages of ordering full (or almost full) trucks.



KPI scorecard

PMS location and structure

Supply Chain Dimension	Name of KPI	No. Of KPI in structure of PMS
☐ Reliability ☑ Efficiency ☐ Responsiveness ☐ Sustainability	Transportation cost per ton km	*On what level in the PMS is the KPI located?* 2.2

Definition and purpose

Link to higher level KPI	Linked to strategic objective
☑ KPI is a top level indicator (Strategic KPI) ☐ Operational KPI and related to;	The products that are bought shall to the largest extent be bought from companies that have the lowest total cost including freight.

Explanation of KPI	Purpose (KPQ)
The average cost [SEK] of transporting one ton of a product group to a project site.	What is the cost of transporting our products?

Calculation and data collection

Formula and unit of KPI	Target
$\frac{Cost\ for\ transporting}{Transported\ weight\ x\ supply\ chain\ miles}$ = Transportation cost [SEK] per ton km	*What is the desirable output of the KPI?* ☑ Minimize ☐ Maximize ☐ Specific value;

Source of Data	
☑ ERP System (Monitor) ☐ Survey ☑ Order tracking system	The cost for transporting should come from the invoice for a certain shipment which is registered in the ERP system at Inköp AB. The transported weight should be registered in the order tracking system at the 3PL which reports into the ERP system.

Level of metric calculation	Intended reporting levels
Which level is the data reporting frequency and calculation conducted at? ☑ Shipment (Per vechicle) ☐ Order ☐ Product Group	*On what level will the data be evaluated and analyzed?* ☐ Shipment (Per vechicle) ☑ Order ☑ Product Group ☑ Supplier ☑ Customer

Reporting and other input

Reporting frequency	Reciever of report	Qualitative input
How often is data evaluated and analyzed? ☐ Daily ☐ Weekly ☑ Monthly ☐ Other	☑ Operative team ☑ Company management ☑ Company board ☐ Suppliers ☐ 3PL ☐ Customer ☐ Other	*Other information that needs to be considered and complements the KPI* In order to acheive a total cost perspective, a comparison of transportation prices within low cost countries would be applicable. This could be done by comparing the cost of transporting from different material suppliers to common used location e.g. a port.

Process owner and responsible department	Release date / Revision
Logistic operator at Inköp AB	XXXX-XX-XX

Figure 5.13: Transportation cost per ton-km

The reason for having this KPI should be to answer the KPQ, which in the case of Inköp AB would be *what is the cost of transporting our products?*. To do so, the KPI transportation cost per ton-km should measure the average cost (in SEK) for shipping one ton of goods for the distance of one km. As can be seen in figure 5.13, the formula for calculating the KPI is to divide the transportation cost with the load weight of the truck (transported weight) and the distance between the supplier and the project site (supply chain miles). The target for the calculation of this KPI should in the case of Inköp AB be to minimize it as much as possible. However, here the same aspect that was mentioned for fill rate applies here as well, meaning that trying to decrease the transportation cost per ton-km too much might require a trade-off for service level, something that is not wanted in the case of Inköp AB. As mentioned before in this report, due to the product and supply characteristics, construction supply chains should aim to be efficient. Thus, both fill rate and transportation cost per ton-km should be considered as two important

KPIs for the logistics PMS of such supply chains. Reducing the transportation cost is a way of eliminating waste and being more efficient, thereby fulfilling the supply chain dimension *"supply chain efficiency"*.

One part of the data that is required for calculating this KPI is the transportation cost, which in Inköp ABs case should be collected from the invoice that the 3PL sends. This should then be reported into the ERP system of Inköp AB. In addition, the load weight and the distance between the supplier and the customer are required for calculating the KPI. Data for these should already be available, and should also be reported into the ERP system. One application area when collecting the transportation cost per ton-km is to compare different suppliers. This would mean that it would be possible to compare the cost differences between suppliers, depending on the volume and the product type that are sourced from each location. Moreover, the distance vehicles travel outside of Sweden could be multiplied with the transportation cost per ton-km. Doing so would make it possible to show the cost differences when sourcing from suppliers located further away.

The data should be calculated for each vehicle, but should be evaluated and analyzed per order. As mentioned before, it should be possible to breakdown and compare the data for each product group, but also to each customer. The results should be reported to the operative team, company management and the company board. Also, the reporting frequency was suggested to be monthly, thereby having an aligned reporting frequency as fill rate.

5.4.3 Responsiveness

According to Bolstorff and Rosenbaum (2012), supply chain responsiveness refers to the speed at which a supply chain provides products to the customer. Furthermore, the uncertainty framework in section 5.3 showed that in the case of Inköp AB, the supply chain was leaning towards a responsive supply chain. This was mostly due to the demand characteristics. Thus, in order to ensure that the supply chain achieves responsiveness, two KPIs were discussed. These KPIs were backlog and customer ordering lead time, which will here be thoroughly explained. This also is aligned with what Azambuja and O'Brien (2009) stated, which was that the information flow in the construction industry is having issues. One way of improving in this area would be to examine the implementation of the KPIs presented in this upcoming section.

Backlog

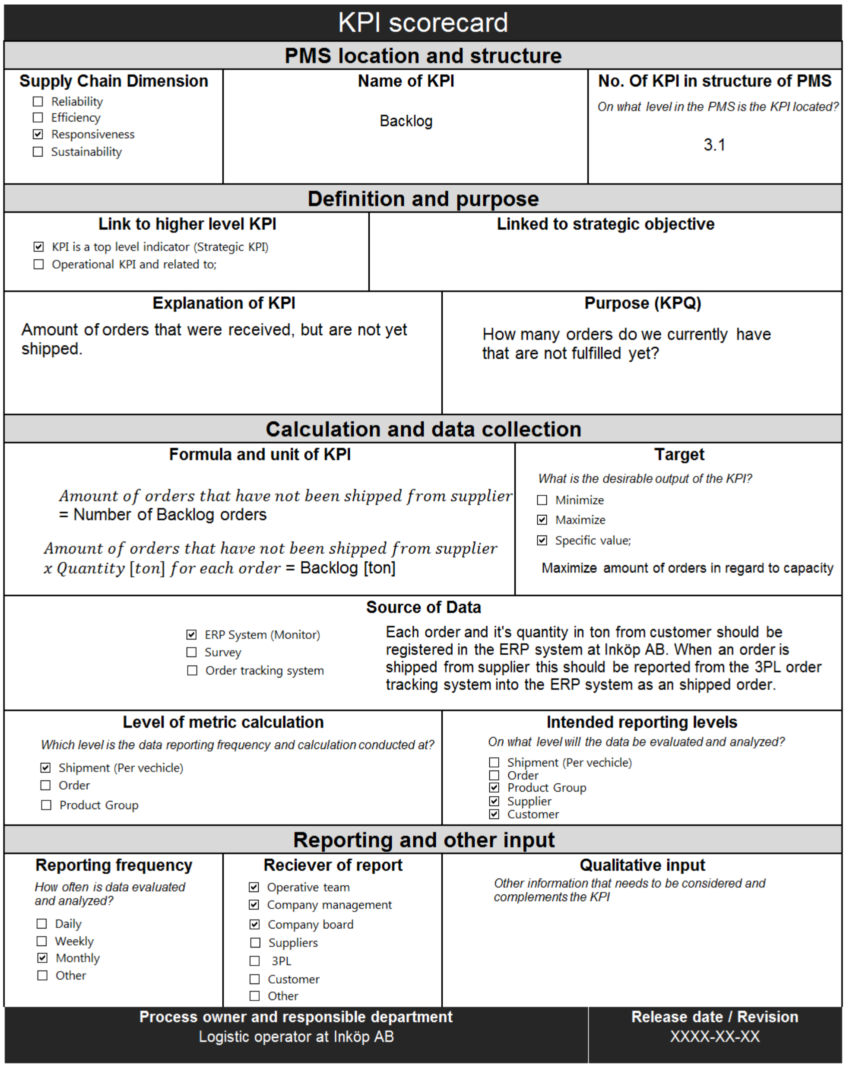
Backlog can be seen as a KPI based on information, and can be explained as the amount of orders that a company has received, but which are not yet shipped. This should also be measured in amount of ton, thereby providing information about how much strain is put on the supply chain of Inköp AB. Knowing the strain should facilitate the process for improving the supply chain responsiveness towards the customers. The KPQ for backlog was *How many orders do we currently have that are not fulfilled yet?*. Knowing the answer to that question should make it possible for the company to facilitate resource allocation, but also in the future make it possible to create forecast with the historical data gathered with backlog. Having some kind of forecasts would be a huge step for the case company, where it currently is almost impossible to forecast, since there are new customers (projects) in almost every order. However, if historical data would be gathered, it should at least be possible to predict some kind of ranges of what the order volumes could be. Thereby the suppliers could be informed, making it easier for them to be reliable and responsive. Currently there is no strategic objective connected to this kind of KPI. However, as mentioned earlier in this master thesis it is very important to connect the KPIs to strategic objectives, thereby clearly communicating to the company what the goal is and why it is important to improve the output of the KPI.

In order to set up this strategic KPI as good as possible, two underlying, operational KPIs were chosen. These two were:

- **Backorder** - This operational KPI should measure the amount of orders that Inköp AB has received, but are not yet shipped and are late. In other words, this KPI measures the orders that are late in the current state, see appendix C.4.
- **Unbooked backlog** - Refers to the amount of orders that Inköp AB has received, but which are not confirmed by material suppliers and 3PL , see appendix C.5. This refers to the orders that still require some work from Inköp AB, which has not yet got confirmation from the suppliers and 3PL that they are able to deliver the required goods to the date and time in the request.

Backlog can be calculated by either counting the amount of orders that have not been shipped, or by measuring the amount of ton that has not been shipped at that point of time. Generally speaking, the target should be to increase the amount of backlog, since this is an indication that there is much work to do. Furthermore, it makes it easier for the order management of the case company to consolidate order and increase fill rate (and decreasing transportation cost per ton-km) when there are more orders to handle. However, if there are not enough resources at Inköp AB to handle an increase in backlog, it should not be targeted to maximize the output of the KPI. The data required to calculate backlog should already exist, which means that the implementation of this KPI should be quite easy. However, the collected data should also be clearly stated and be reported into an ERP system of the supply chain. When the order is shipped a signal from the order tracking is required to indicate to the ERP system that the order has been shipped.

Backlog should be reported monthly towards the operative team, company management and company board, since it thereby ensures an aligned understanding of the utilized capacity of the resources at Inköp AB. Also, the KPI should be reported and broken down into different levels, e.g. product groups, suppliers and customers. Doing so would make it possible to find different reason and aspects to why the



KPI scorecard

PMS location and structure

Supply Chain Dimension	Name of KPI	No. Of KPI in structure of PMS
☐ Reliability ☐ Efficiency ☑ Responsiveness ☐ Sustainability	Backlog	*On what level in the PMS is the KPI located?* 3.1

Definition and purpose

Link to higher level KPI	Linked to strategic objective
☑ KPI is a top level indicator (Strategic KPI) ☐ Operational KPI and related to;	

Explanation of KPI	Purpose (KPQ)
Amount of orders that were received, but are not yet shipped.	How many orders do we currently have that are not fulfilled yet?

Calculation and data collection

Formula and unit of KPI	Target
$\sum$ *Amount of orders that have not been shipped from supplier* = Number of Backlog orders $\sum$ *Amount of orders that have not been shipped from supplier x Quantity [ton] for each order* = Backlog [ton]	*What is the desirable output of the KPI?* ☐ Minimize ☑ Maximize ☑ Specific value; Maximize amount of orders in regard to capacity

Source of Data

☑ ERP System (Monitor)
☐ Survey
☐ Order tracking system

Each order and it's quantity in ton from customer should be registered in the ERP system at Inköp AB. When an order is shipped from supplier this should be reported from the 3PL order tracking system into the ERP system as an shipped order.

Level of metric calculation	Intended reporting levels
Which level is the data reporting frequency and calculation conducted at? ☑ Shipment (Per vechicle) ☐ Order ☐ Product Group	*On what level will the data be evaluated and analyzed?* ☐ Shipment (Per vechicle) ☐ Order ☑ Product Group ☑ Supplier ☑ Customer

Reporting and other input

Reporting frequency	Reciever of report	Qualitative input
How often is data evaluated and analyzed? ☐ Daily ☐ Weekly ☑ Monthly ☐ Other	☑ Operative team ☑ Company management ☑ Company board ☐ Suppliers ☐ 3PL ☐ Customer ☐ Other	*Other information that needs to be considered and complements the KPI*

Process owner and responsible department	Release date / Revision
Logistic operator at Inköp AB	XXXX-XX-XX

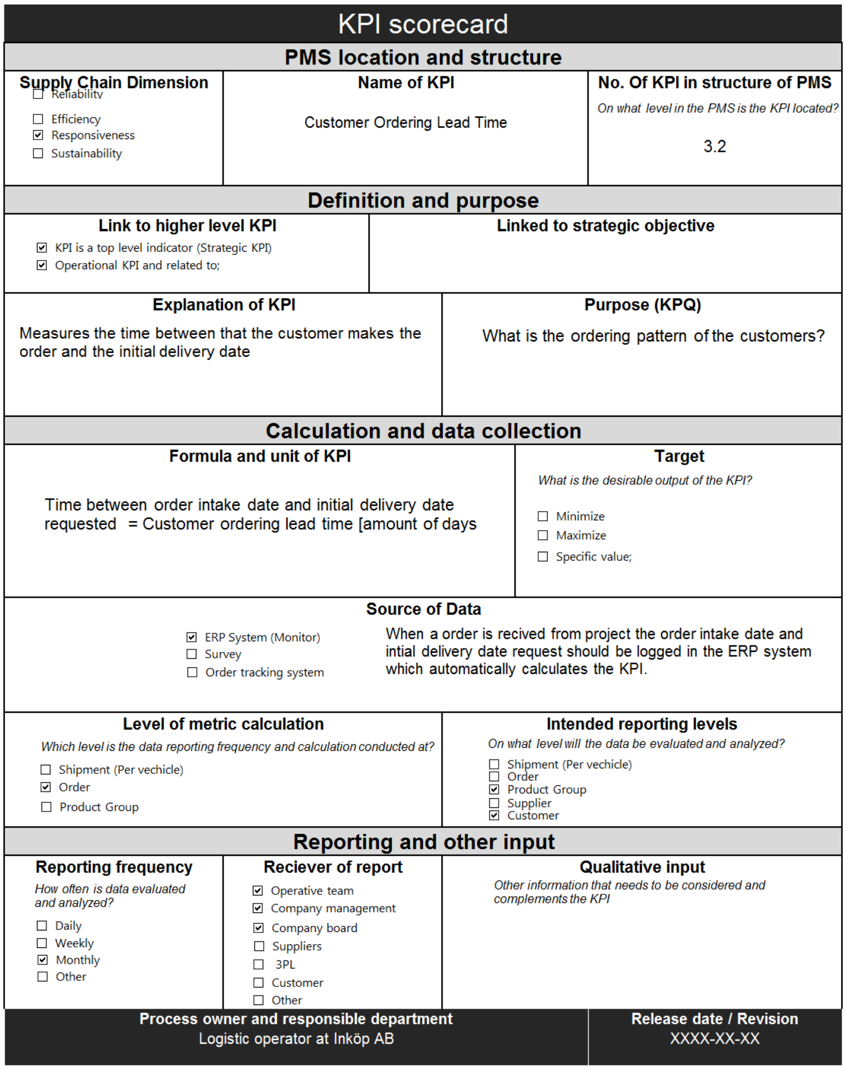
Figure 5.14: Backlog

backlog is high or low. However, the KPI should be calculated for each shipment.

Customer ordering lead time

Customer ordering lead time is a KPI which aims to identify the ordering patterns of the customers to construction companies, meaning the projects. The reason for wanting to examine such ordering patterns is that some of the interviewees complained of an uncertainty regarding the ordering patterns from customers. According to the interviewees there is currently no real information of how often a project is ordering too late and therefore can not receive the deliveries to their initial requested date. For this reason, customer ordering lead time was deemed necessary to implement for the case company. The KPI should measure the time between an order is made and the initially requested delivery date. Doing so should help to visualize if the customers do send the orders on time, or if they often order with a too short lead time, making it difficult for the rest of the supply chain to respond on time.

The data that is required for calculating this KPI should already exist in the current system of the case company, although the data in the future should also be logged in the ERP system. The result of that kind of calculation would be done for every order and be measured in amount of days. No target was stated in figure 5.15, since the ordering lead time often depends on the circumstances of the customer. However, in general the target should be to maximize the amount of days, since this gives both the supplier and Inköp AB more time to perform perfectly, and makes it easier to plan the different parts of the delivery.



KPI scorecard

PMS location and structure

Supply Chain Dimension
☐ Reliability
☐ Efficiency
☑ Responsiveness
☐ Sustainability

Name of KPI
Customer Ordering Lead Time

No. Of KPI in structure of PMS
On what level in the PMS is the KPI located?
3.2

Definition and purpose

Link to higher level KPI
☑ KPI is a top level indicator (Strategic KPI)
☑ Operational KPI and related to;

Linked to strategic objective

Explanation of KPI
Measures the time between that the customer makes the order and the initial delivery date

Purpose (KPQ)
What is the ordering pattern of the customers?

Calculation and data collection

Formula and unit of KPI
Time between order intake date and initial delivery date requested = Customer ordering lead time [amount of days

Target
What is the desirable output of the KPI?
☐ Minimize
☐ Maximize
☐ Specific value;

Source of Data
☑ ERP System (Monitor)
☐ Survey
☐ Order tracking system
When a order is recived from project the order intake date and intial delivery date request should be logged in the ERP system which automatically calculates the KPI.

Level of metric calculation
Which level is the data reporting frequency and calculation conducted at?
☐ Shipment (Per vechicle)
☑ Order
☐ Product Group

Intended reporting levels
On what level will the data be evaluated and analyzed?
☐ Shipment (Per vechicle)
☐ Order
☑ Product Group
☐ Supplier
☑ Customer

Reporting and other input

Reporting frequency
How often is data evaluated and analyzed?
☐ Daily
☐ Weekly
☑ Monthly
☐ Other

Reciever of report
☑ Operative team
☑ Company management
☑ Company board
☐ Suppliers
☐ 3PL
☐ Customer
☐ Other

Qualitative input
Other information that needs to be considered and complements the KPI

Process owner and responsible department
Logistic operator at Inköp AB

Release date / Revision
XXXX-XX-XX

Figure 5.15: Customer ordering lead time

The KPI should be calculated per order, but should be reported as an average over a larger time period, e.g. per month. It would also be intresting to break down the data of the KPI for product groups, thereby examining if there are some products that generally are ordered with less reaction time for the supply chain. In addition, different types of projects should be analyzed, since some pattern for certain types of projects might be identified. This could for example mean that hospital projects generally give more ordering lead time than refurbishment projects. Knowing such patterns should possibly making it easier for Inköp AB to prepare for upcoming orders from such projects. Customer ordering lead time should be reported to the operative team, company management and the company board. If some patterns are identified, countermeasures should be taken, which e.g. could mean communicating with projects about not ordering certain products too late, since that might lead to late deliveries.

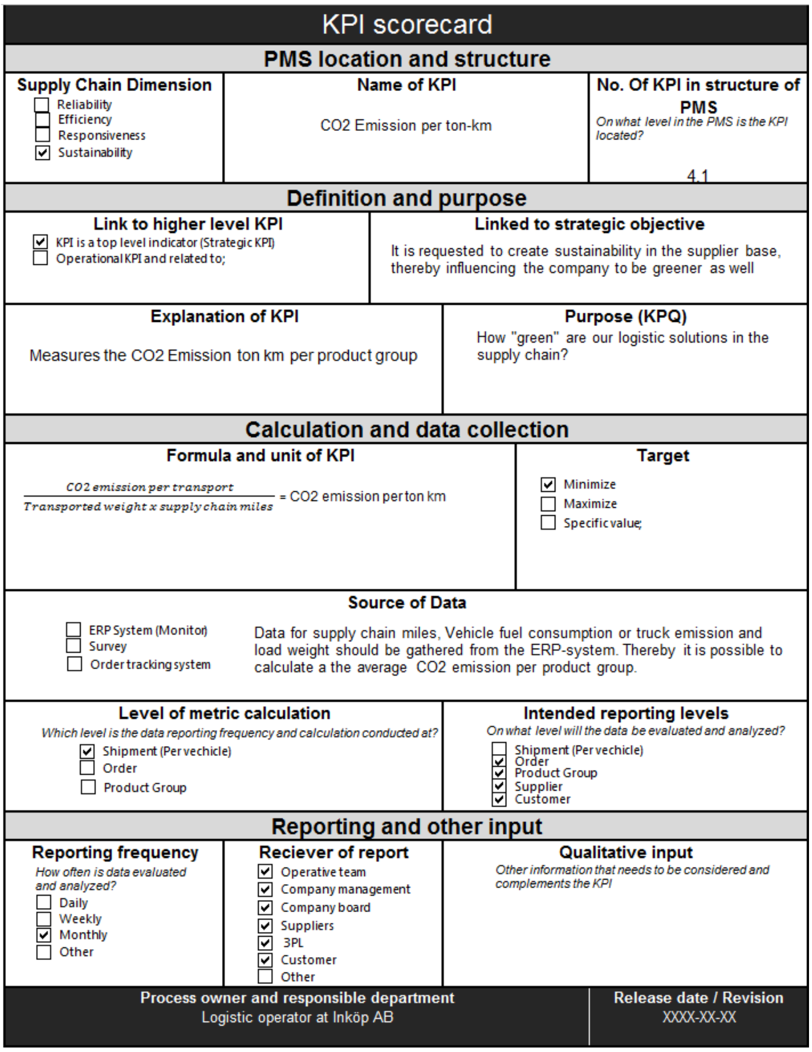
5.4.4 Sustainability

The theme sustainability was considered to be very important by many interviewees, which also concluded that there currently is no existing KPI that measures and provides information on how environmentally sustainable the case company Inköp AB really is. Since a lot of customers in construction supply chains are from the public sector, there has been an increasing demand towards sustainable processes and so called *"Green solutions"*. In order to measure how environmental sustainable construction supply chains are, a KPI was suggested which measures the emission of CO2. Measuring the sustainability like that could also be a sales argument, depending on how the result of the KPI is. According to several interviewees, the main focus should lie on just trying to introduce one environmental sustainability KPI, thereby slowly creating an increasing focus on it. There were a number of other suggestions as well, e.g. measuring waste or NOx emsissions. However, the interviewees claimed that having a well known KPI which would be able to be compared with other industries would be the most suitable to implement. Therefore it was suggested that CO2 emission per ton-km should be introduced as a KPI for construction supply chains.

CO2 emission per ton-km

The KPQ for this sustainability KPI was *"How green are the logistics solutions in the supply chain?"*. Lately, there has been an initiative at Inköp AB to have a “greener” approach, trying to be more sustainable than before. One example of this was that the business plan currently stated that creation of sustainability in the supplier base was a strategic objective. As stated in the literature by Ortiz et al. (2009), the construction industry is a big part of the environmental sustainability, where it is responsible for high-energy consumption and waste-generation. Understanding the need of being more sustainable, the majority of members in the reference group agreed that CO2 emission per ton-km would be important to measure. Another aspect that adds weight to having a KPI that is connected to the environmental sustainability is that a large part of the customers are from the public sector, e.g. meaning that they may collect subsidiaries from the government. Since the countries in Scandinavia could be considered of being in upfront in the sustainability area, it should be expected to be of high importance in the upcoming years as mentioned by Ortiz et al. (2009).

Measuring the CO2 emission is something that is already done in big parts of today’s



KPI scorecard

PMS location and structure

Supply Chain Dimension
- [ ] Reliability
- [ ] Efficiency
- [ ] Responsiveness
- [x] Sustainability

Name of KPI

CO2 Emission per ton-km

No. Of KPI in structure of PMS

On what level in the PMS is the KPI located?

4.1

Definition and purpose

Link to higher level KPI
- [x] KPI is a top level indicator (Strategic KPI)
- [ ] Operational KPI and related to;

Linked to strategic objective

It is requested to create sustainability in the supplier base, thereby influencing the company to be greener as well

Explanation of KPI

Measures the CO2 Emission ton km per product group

Purpose (KPQ)

How "green" are our logistic solutions in the supply chain?

Calculation and data collection

Formula and unit of KPI

$$\frac{CO2\ emission\ per\ transport}{Transported\ weight\ x\ supply\ chain\ miles} = \text{CO2 emission per ton km}$$

Target
- [x] Minimize
- [ ] Maximize
- [ ] Specific value;

Source of Data
- [ ] ERP System (Monitor)
- [ ] Survey
- [ ] Order tracking system

Data for supply chain miles, Vehicle fuel consumption or truck emission and load weight should be gathered from the ERP-system. Thereby it is possible to calculate a the average CO2 emission per product group.

Level of metric calculation

Which level is the data reporting frequency and calculation conducted at?
- [x] Shipment (Per vechicle)
- [ ] Order
- [ ] Product Group

Intended reporting levels

On what level will the data be evaluated and analyzed?
- [ ] Shipment (Per vechicle)
- [x] Order
- [x] Product Group
- [x] Supplier
- [x] Customer

Reporting and other input

Reporting frequency

How often is data evaluated and analyzed?
- [ ] Daily
- [ ] Weekly
- [x] Monthly
- [ ] Other

Reciever of report
- [x] Operative team
- [x] Company management
- [x] Company board
- [x] Suppliers
- [x] 3PL
- [x] Customer
- [ ] Other

Qualitative input

Other information that needs to be considered and complements the KPI

Process owner and responsible department

Logistic operator at Inköp AB

Release date / Revision

XXXX-XX-XX

Figure 5.16: CO2 emission per ton-km

society, which should make it suitable to use as KPI for construction supply chains and for the case study as well. Since these types of emission is already measured in society, it becomes easier to compare and understand whether the result is good or bad. As stated by one of the interviewees: *"We can measure, but what does it actually mean?"*. The interviewee was referring to if the KPI only show some various number that make it difficult to understand if the result is really good or bad. From this perspective, having a KPI like CO2 emission per ton-km should be seen as very advantageous. The KPI should be calculated by collecting the data for how far each vehicle has to travel (distance), the vehicle fuel consumption, and the load weight that was transported in each vehicle. The target should naturally be to minimize the result, thereby contionusly working towards sustainability.

The KPI focuses on the transport of goods, and should calculate how much CO2 emission is created in the various transports. The KPI should be calculated by dividing the emission of one transport by both the transported weight and the supply chain miles. Naturally, the target should be to minimize the output of this KPI and have as low CO2 emission as possible, although the case company might have some specific value or target that they would like to achieve and aim for. The result of the KPI could then be reported as positive publicity towards the projects, making sustainability a cause to why the projects should choose to work with a company.

5.4.5 Interrelations between the KPIs

When developing KPIs and implementing a logistics PMS as presented above, it is critical to understand the interrelations between the chosen KPIs. These interrelations refer to the fact that a positive impact on one of the KPIs might at the same time influence another KPI in some way. One example was already mentioned in the previous chapter, where it was stated that fill rate and transportation cost per ton-km often change in the same ways as the other. A similar connection could be observed between CO2 emission per ton-km, and the previously mentioned KPIs, fill rate and transportation cost per ton-km. This interrelation refers to that if for example the fill rate increases, this will also have a positive effect on CO2 emissions per ton-km.

Another interesting interrelation is between perfect order fulfillment and the efficiency KPIs, fill rate and transportation cost per ton-km. Here it could be argued that if the focus is on just improving both the fill rate and the transportation cost per ton-km, there is a risk of decreasing the service level. The service level is a factor in the reliability dimension, thereby possibly affecting the POF in a negative way. Another interrelation can be seen between backlog order and customer ordering lead times. There the backlog order would clearly increase if the ordering lead times would improve.

6 Conclusion

In this section the research questions are answered, followed by a short recommendation towards the case company of this report. Lastly, suggestions to further research are stated.

6.1 Answering of research questions

The aim of this master thesis was to investigate and give suggestions how to measure the logistics performance of a construction supply chain. In order to do so, two research questions were answered.

RQ1. How should a logistics performance measurement system for a construction supply chain be designed?

One of the main findings of this master thesis was the conceptual framework that was created, which focused on designing a logistics PMS. The framework was developed based on recommendations from various literature sources, and should be applicable to all kinds of companies. The framework takes company, industry, and supply chain characteristics into consideration, and helps design the logistics PMS around those findings. The conceptual framework was divided into four steps, see figure 6.1.

The first research question (RQ1) referred especially to construction supply chains. When looking at the construction industry, it is important to keep in mind that every project is unique, which also makes each supply chain setup unique. However, it was still possible to find generalities and consistencies that characterized the construction industry. These findings were analyzed and applied to the conceptual framework in order to find which different dimensions that a logistics PMS in a construction supply chain should cover.

Doing so resulted in the finding of four supply chain dimensions. By analyzing the business context and supply chain processes in construction supply chains, one dimension that should be covered was found to be supply chain reliability. Furthermore, analyzing the demand- and supply characteristics of construction supply chains gave that their supply chains should cover efficiency, but also responsiveness in some degree. Lastly, a rising awareness and focus on sustainability was found to be important in construction supply chains. In conclusion, this meant that construction supply chains should follow the conceptual framework when designing a

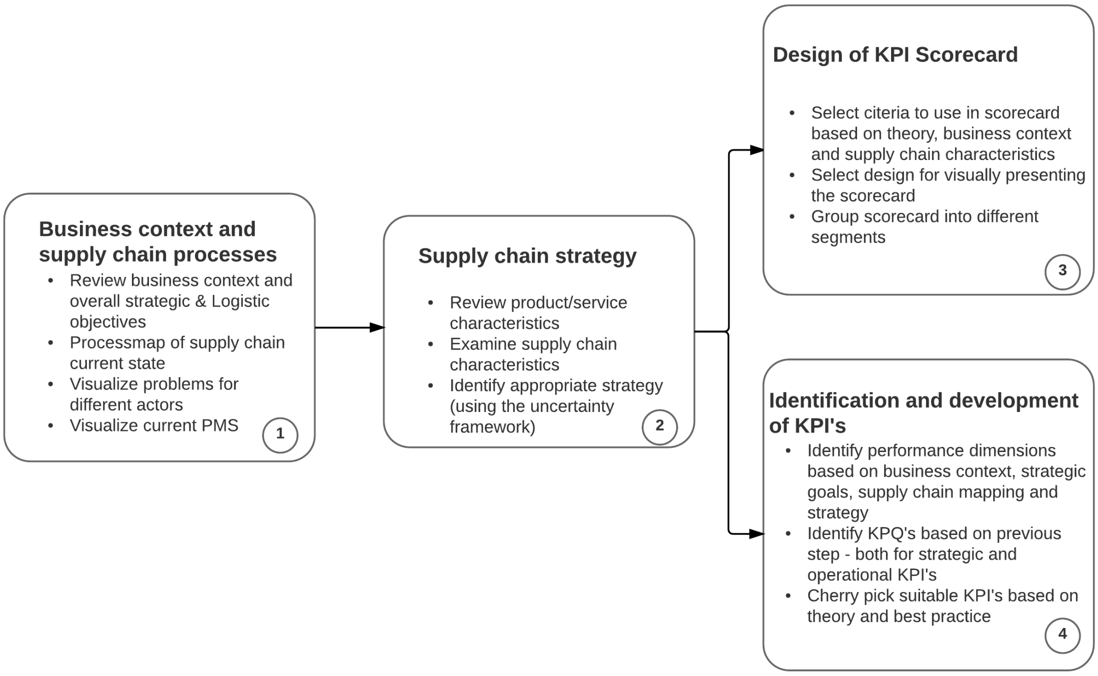


Figure 6.1: Conceptual Framework - Design of logistics PMS

logistics PMS. In addition, the logistics PMS for construction supply chains should be structured around the four supply chain dimensions that were identified in this research: reliability, efficiency, responsiveness and sustainability.

RQ2. Which KPIs should be included in a logistics performance measurement system of a construction supply chain?

In order to answer the second research question, the conceptual framework was used. By following the different steps in the conceptual framework (see figure 6.1, it should be ensured that the specific context of the company and its supply chain characteristics has been taken into account when selecting KPIs. As can be seen in figure 6.1, the last step in the conceptual framework was the identification and development of KPIs. Here the supply chain dimensions which were described in RQ1 should be the basis for what areas the KPIs should cover, taking into account what business context, strategic goals, supply chain mapping and strategy that were found in connection to construction supply chains.

In order to choose which KPIs to include in a logistics PMS for construction supply chains, the framework suggested to cherry pick suitable KPIs based on theory and best practice. Thereby a set of KPIs was selected:

- Perfect order fulfillment (POF)
- Fill rate
- Transportation cost per ton-km
- Backlog

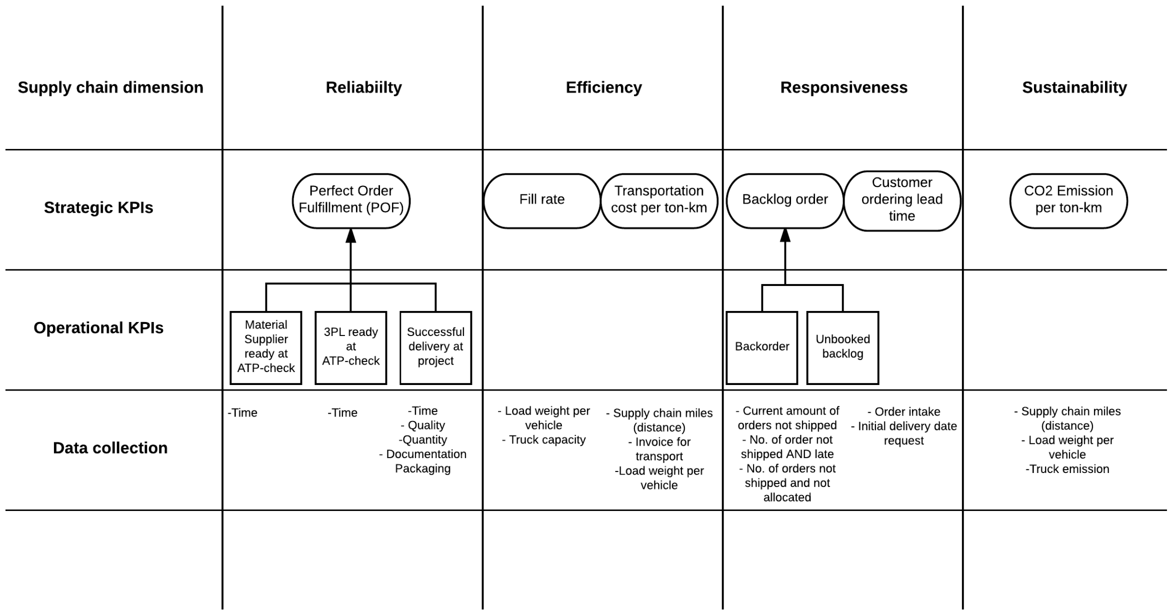


Figure 6.2: Overview of suggested logistics PMS

- Customer ordering lead time
- CO2 emission per ton-km

As can be seen in figure 6.2, six strategic KPIs were identified to be suitable for construction supply chains. Each of the KPIs were meant to cover parts of the dimensions that were found. In addition, five operational KPIs were also selected in order to support two of the previously mentioned strategic KPIs. All these KPIs are suitable KPIs that effectively cover the four dimensions which were deemed to be necessary to cover in a logsitics PMS for a construction supply chain.

6.2 Further research

One finding that would be interesting to put further research into would be the conceptual framework that was presented in this master thesis. The framework was based on mainly qualitative data, and has not been validated in real cases other than in the case study of this research. Thus, it would be intresting to try to validate and solidify the utility of the framework by conducting quantitative research about it.

Furthermore, one of the main flaws of this research was considered to be that many findings were based on the single case study. The conclusions that were made for the construction industry were mainly drawn from theory and should be validated and verified by conducting multiple case studies. Thereby it should be able to compare its usefulness within different contexts and different industries.

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A

Appendix - SCOR

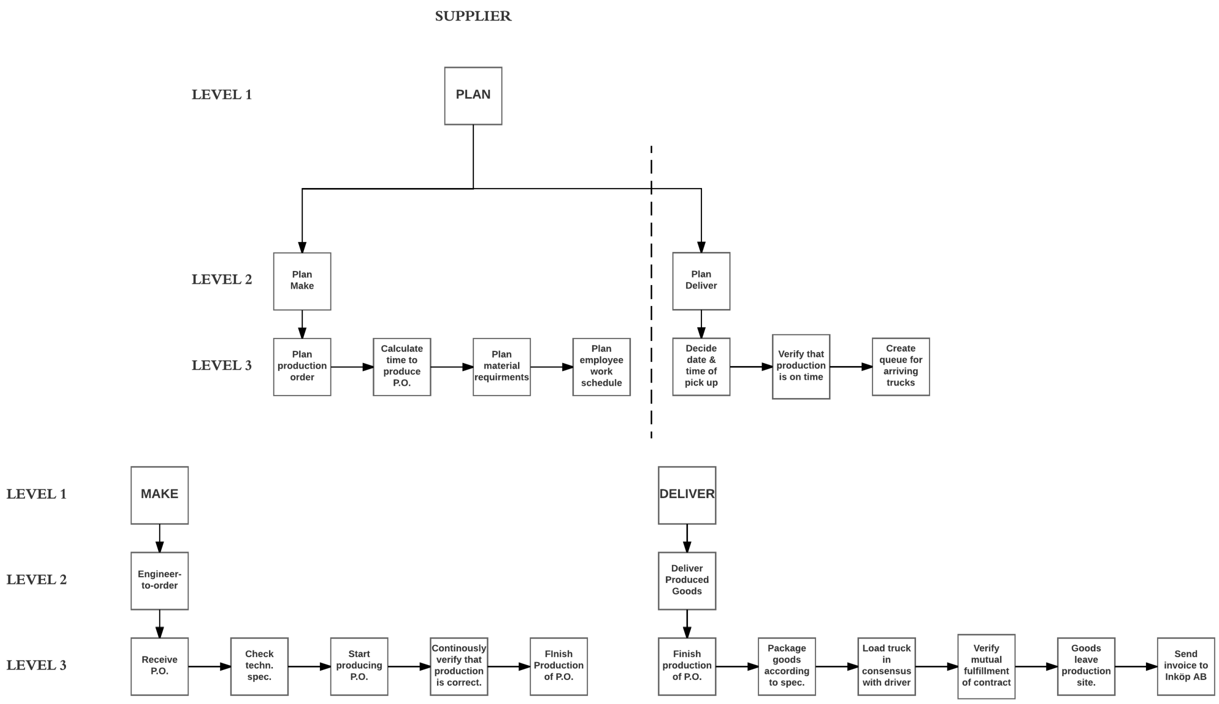


Figure A.1: Material supplier processes

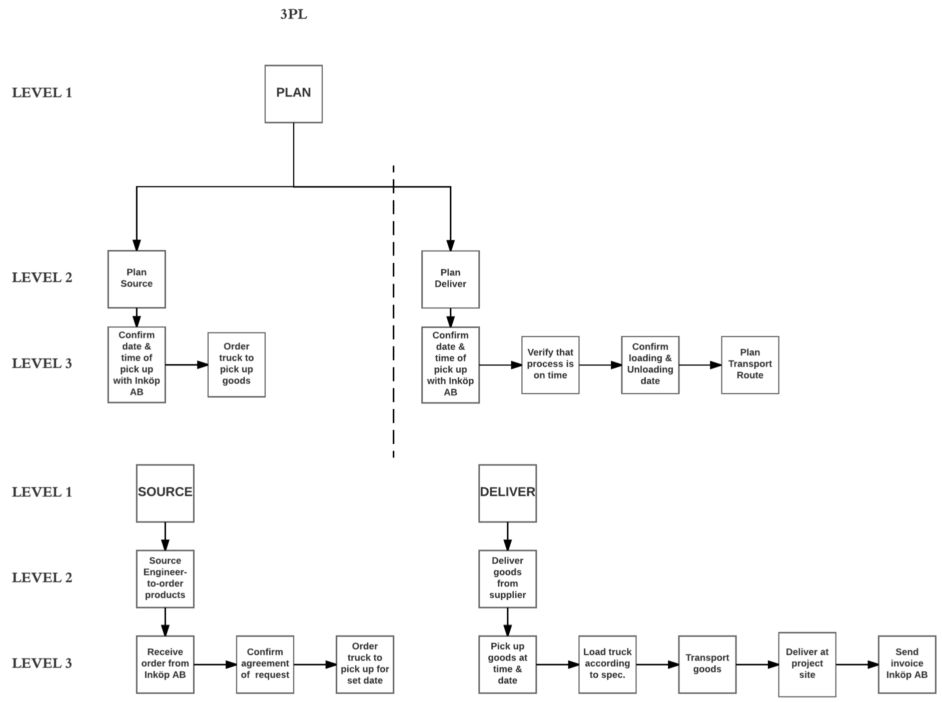


Figure A.2: 3PL processes

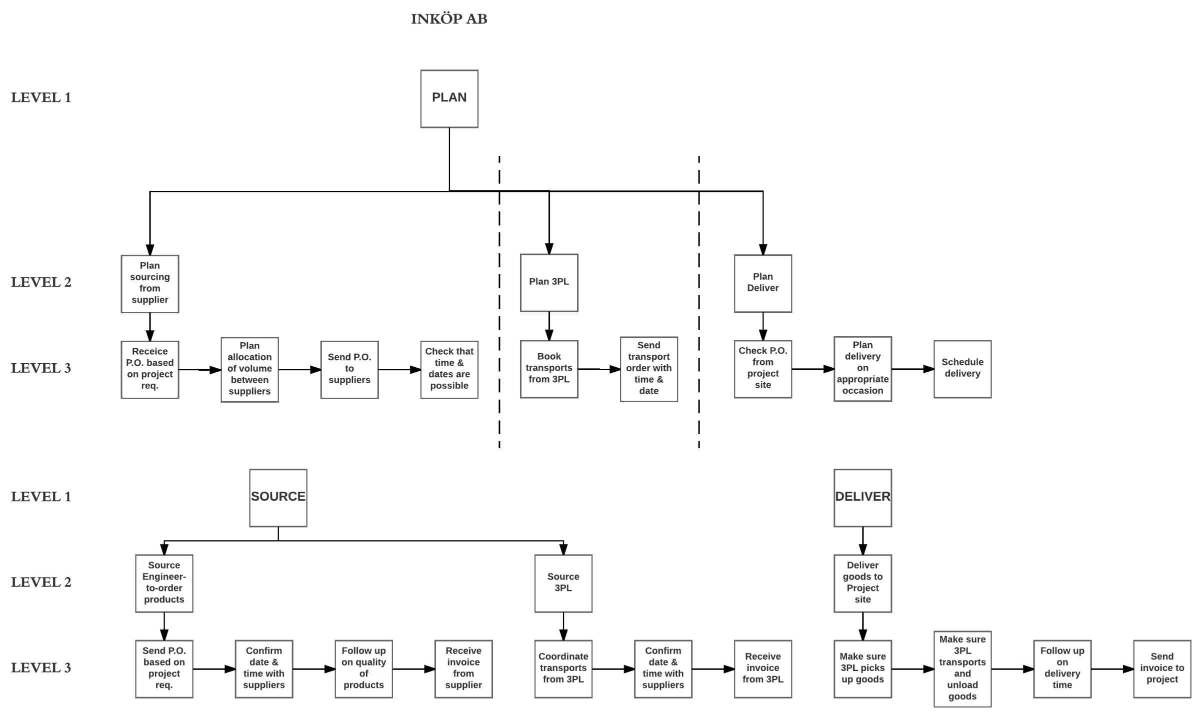


Figure A.3: Inköp AB processes

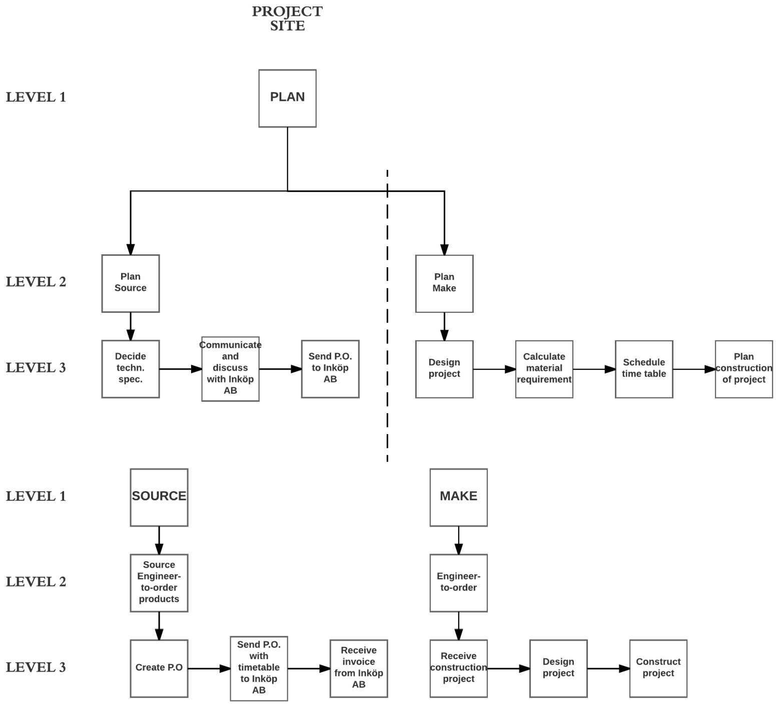


Figure A.4: Project site processes

B

Appendix - Interview questions

B.1 Supply Chain Mapping

- What is your responsibilities and position in the supply chain?
- How does your process look like - stepwise?
- What is the input (information) you get to your position?
- Do you use any metrics (KPI's) or performance measurement?
  - If yes, which?
  - If no, why not?
  - Do you think these are sufficient?
  - How could it be improved, redefined or suggest new?
  - What is the actual level and what is the targeted?
  - How are the KPIs defined? Which unit etc.?
- What tools do you currently use?
  - Do you think these are sufficient?
  - How could it be improved or suggest new?
- What is the output of your process?
- What is the lead time of the total process?
- What do you think are the main issues with the current Inköp AB supply chain?
  - What are main reasons behind the issue/s?
  - Who is responsible?
  - How could it be improved?
  - Could Inköp AB do something in order to improve the current state?
- How many suppliers are there for the reinforcement category currently?
  - Where is each and everyone located?
- Does the project manager provide a review of Inköp AB logistics performance?

B.2 Input to Inköp AB Supplier

- What RFQs are currently sent to the suppliers?
  - How are they structured?
  - What is specified?
  - What is promised from Inköp ABs side?
  - What is expected by the supplier?
  - Are there any sanctions stated on the supplier if RFQ isn't fulfilled?

- What are the logistics specifications that Inköp AB has agreed upon with the supplier in the contract?
  - Are there any KPI's that have to be fulfilled (e.g. delivery precision, fill rate)?

B.3 Inköp AB Supplier performance

- How are the suppliers selected?
  - Solely on price or are there other aspects as well?
  - Are there any existing comparisons between suitable suppliers?
  - What circumstances must exist in order for a supplier to be cut off?
- What lead times does the supplier need to produce the reinforcements needed? How long before must the order have been made?

B.4 Coordination from Inköp AB

- How is the communication with 3PL structured?
  - Who is responsible?
- What is Inköp AB responsible for in the supply chain?
  - What specific activities do Inköp ABf perform?
- What is 3PL responsible for the in supply chain?
  - What specific activities do 3PL perform?

C

Appendix - Operational KPIs

KPI scorecard

PMS location and structure

Supply Chain Dimension	Name of KPI	No. Of KPI in structure of PMS
☐ Reliability ☐ Efficiency ☐ Responsiveness ☐ Sustainability	Material supplier ready at ATP check	*On what level in the PMS is the KPI located?* 1.1.1

Definition and purpose

Link to higher level KPI	Linked to strategic objective
☐ KPI is a top level indicator (Strategic KPI) ☑ Operational KPI and related to; Perfect Order Fulfillment (POF)	Business plan logistics; Achieve a 99 % delivery precision

Explanation of KPI	Purpose (KPQ)
Measures how often the material suppliers fulfill the agreed time and date towards the 3PL. If material supplier is on time = Order is fulfilled, If material supplier is not on time = Order is not fulfilled	Contributing to the perfect order fulfillment (POF) - How often is the material supplier on time and what differences are there between material suppliers

Calculation and data collection

Formula and unit of KPI	Target
$\frac{\text{Amount of } material\ supplier\ ATP}{\text{Amount of } deliveries} \times 100 = \%\ material\ supplier\ ATP$	*What is the desirable output of the KPI?* ☐ Minimize ☑ Maximize ☐ Specific value;

Source of Data

☐ ERP System (Monitor)
☐ Survey
☑ Order tracking system

3PL reports in if material supplier were ready at set time and date. The data should orginally come from the 3PL order tracking system which should report in to the ERP system.

Level of metric calculation	Intended reporting levels
Which level is the data reporting frequency and calculation conducted at? ☑ Shipment (Per vechicle) ☐ Order ☐ Product Group	*On what level will the data be evaluated and analyzed?* ☑ Shipment (Per vechicle) ☑ Order ☐ Product Group ☑ Supplier ☐ Customer

Reporting and other input

Reporting frequency	Reciever of report	Qualitative input
How often is data evaluated and analyzed? ☐ Daily ☐ Weekly ☑ Monthly ☐ Other	☑ Operative team ☑ Company management ☑ Company board ☑ Suppliers ☑ 3PL ☐ Customer ☐ Other	*Other information that needs to be considered and complements the KPI*

Process owner and responsible department	Release date / Revision
Logistic operator at Inköp AB	XXXX-XX-XX

Figure C.1: Material supplier ready at ATP check

KPI scorecard

PMS location and structure

Supply Chain Dimension
- [x] Reliability
- [ ] Efficiency
- [ ] Responsiveness
- [ ] Sustainability

Name of KPI

3PL ready at ATP check

No. Of KPI in structure of PMS

On what level in the PMS is the KPI located?

1.1.2

Definition and purpose

Link to higher level KPI
- [ ] KPI is a top level indicator (Strategic KPI)
- [x] Operational KPI and related to;

Perfect Order Fulfillment (POF)

Linked to strategic objective

Business plan logistics; Achieve a 99 % delivery precision

Explanation of KPI

Measures how often the 3PL fulfill the agreed time and date at the material supplier. Meaning If 3PL is on time = Order is fulfilled, If 3PL is not on time = Order is not fulfilled

Purpose (KPQ)

Contributing to the perfect order fulfillment (POF) - How often is the 3PL on time at the material supplier

Calculation and data collection

Formula and unit of KPI

$$\frac{\text{Amount of } 3PL\ ready\ ATP}{\text{Amount of } deliveries} \times 100 = \%\ 3PL\ ready\ ATP$$

Target

What is the desirable output of the KPI?
- [ ] Minimize
- [x] Maximize
- [ ] Specific value;

Source of Data
- [ ] ERP System (Monitor)
- [ ] Survey
- [x] Order tracking system

3PL reports in if material supplier were ready at set time and date. The data should orginally come from the 3PL order tracking system which should report in to the ERP system.

Level of metric calculation

Which level is the data reporting frequency and calculation conducted at?
- [x] Shipment (Per vechicle)
- [ ] Order
- [ ] Product Group

Intended reporting levels

On what level will the data be evaluated and analyzed?
- [x] Shipment (Per vechicle)
- [x] Order
- [ ] Product Group
- [ ] Supplier
- [ ] Customer

Reporting and other input

Reporting frequency

How often is data evaluated and analyzed?
- [ ] Daily
- [ ] Weekly
- [x] Monthly
- [ ] Other

Reciever of report
- [x] Operative team
- [x] Company management
- [x] Company board
- [x] Suppliers
- [x] 3PL
- [ ] Customer
- [ ] Other

Qualitative input

Other information that needs to be considered and complements the KPI

Process owner and responsible department

Logistic operator at Inköp AB

Release date / Revision

XXXX-XX-XX

Figure C.2: 3PL ready at ATP check

KPI scorecard

PMS location and structure

Supply Chain Dimension	Name of KPI	No. Of KPI in structure of PMS
☑ Reliability ☐ Efficiency ☐ Responsiveness ☐ Sustainability	Sucessful delivery at Project	*On what level in the PMS is the KPI located?* 1.1.3

Definition and purpose

Link to higher level KPI	Linked to strategic objective
☐ KPI is a top level indicator (Strategic KPI) ☑ Operational KPI and related to; Perfect Order Fulfillment (POF)	Business plan logistics; Achieve a 99 % delivery precision

Explanation of KPI	Purpose (KPQ)
Measures how often the delivery towards project site is sucessful according to following criteria; **Time** - not late or early (+- buffer according customer requirements), **Packaging of product** - Correct on truck and per product, **Quality** - Right product, Meeting technical requirements and right condition , **Quantity** - right number / tonage, **Documentation** - Right documentation Included	Contributing to the perfect order fulfillment (POF) - How often is the delivery towards project site sucessful, according criteras

Calculation and data collection

Formula and unit of KPI

$$\frac{Amount\ of\ sucessfull\ deliveries\ at\ project}{Amount\ of\ deliveries} \times 100$$ = % Sucessful delivery at Project

Furthermore, possibility to breakdown to critiera fullfillment by using;

$$\frac{Amount\ of\ sucessful\ deliveries\ with\ CRITERION}{Amount\ of\ deliveries} \times 100$$ = % Sucessful delivery with a certain criterion

Target

What is the desirable output of the KPI?

☐ Minimize
☑ Maximize
☐ Specific value;

Source of Data

☐ ERP System (Monitor)
☑ Survey
☑ Order tracking system

Project reports in via a digitalized customer survey all listed criteria, answering YES or NO, in order to determine if there was a sucessful delivery at project. The data should be transfered to the ERP system at Inköp AB.

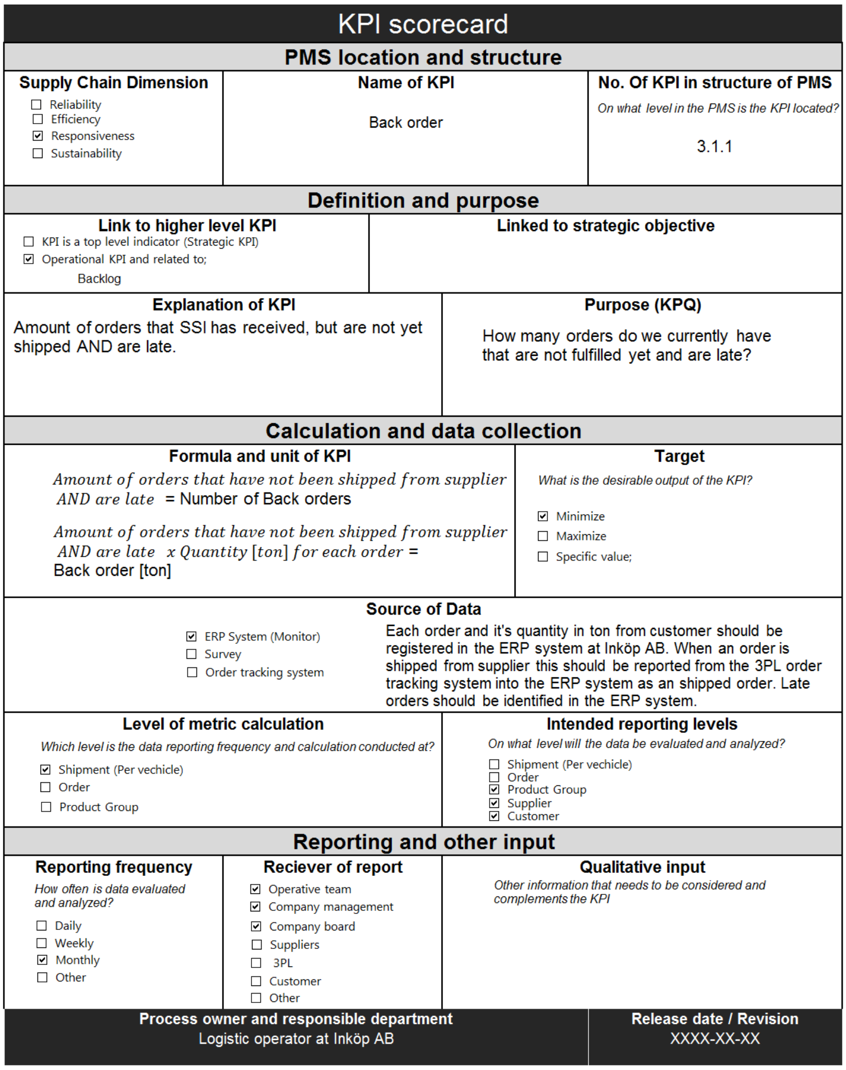
Level of metric calculation	Intended reporting levels
Which level is the data reporting frequency and calculation conducted at? ☑ Shipment (Per vechicle) ☐ Order ☐ Product Group	*On what level will the data be evaluated and analyzed?* ☐ Shipment (Per vechicle) ☑ Order ☑ Product Group ☑ Supplier ☑ Customer

Reporting and other input

Reporting frequency	Reciever of report	Qualitative input
How often is data evaluated and analyzed? ☐ Daily ☐ Weekly ☑ Monthly ☐ Other	☑ Operative team ☑ Company management ☑ Company board ☑ Suppliers ☑ 3PL ☑ Customer ☐ Other	*Other information that needs to be considered and complements the KPI* Observe that POF is affected equally by all measured criteria. Meaning for example that a documentation error has the same "importance" as not delivered in time.

Process owner and responsible department	Release date / Revision
Logistic operator at Inköp AB	XXXX-XX-XX

Figure C.3: Successful delivery at project



KPI scorecard

PMS location and structure

Supply Chain Dimension	Name of KPI	No. Of KPI in structure of PMS
☐ Reliability ☐ Efficiency ☑ Responsiveness ☐ Sustainability	Back order	*On what level in the PMS is the KPI located?* 3.1.1

Definition and purpose

Link to higher level KPI	Linked to strategic objective
☐ KPI is a top level indicator (Strategic KPI) ☑ Operational KPI and related to; Backlog	

Explanation of KPI	Purpose (KPQ)
Amount of orders that SSI has received, but are not yet shipped AND are late.	How many orders do we currently have that are not fulfilled yet and are late?

Calculation and data collection

Formula and unit of KPI	Target
$Amount\ of\ orders\ that\ have\ not\ been\ shipped\ from\ supplier\ AND\ are\ late$ = Number of Back orders $Amount\ of\ orders\ that\ have\ not\ been\ shipped\ from\ supplier\ AND\ are\ late\ \ x\ Quantity\ [ton]\ for\ each\ order$ = Back order [ton]	*What is the desirable output of the KPI?* ☑ Minimize ☐ Maximize ☐ Specific value;

Source of Data

☑ ERP System (Monitor) ☐ Survey ☐ Order tracking system	Each order and it's quantity in ton from customer should be registered in the ERP system at Inköp AB. When an order is shipped from supplier this should be reported from the 3PL order tracking system into the ERP system as an shipped order. Late orders should be identified in the ERP system.

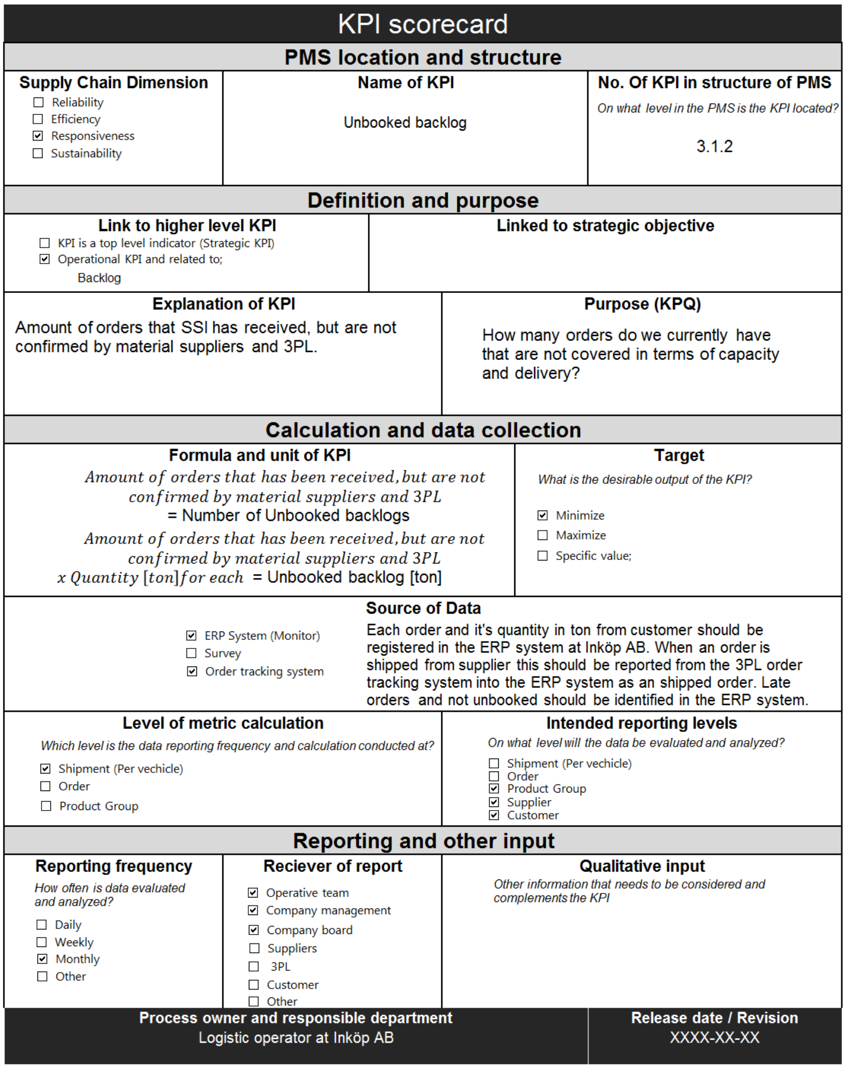
Level of metric calculation	Intended reporting levels
Which level is the data reporting frequency and calculation conducted at? ☑ Shipment (Per vechicle) ☐ Order ☐ Product Group	*On what level will the data be evaluated and analyzed?* ☐ Shipment (Per vechicle) ☐ Order ☑ Product Group ☑ Supplier ☑ Customer

Reporting and other input

Reporting frequency	Reciever of report	Qualitative input
How often is data evaluated and analyzed? ☐ Daily ☐ Weekly ☑ Monthly ☐ Other	☑ Operative team ☑ Company management ☑ Company board ☐ Suppliers ☐ 3PL ☐ Customer ☐ Other	*Other information that needs to be considered and complements the KPI*

Process owner and responsible department	Release date / Revision
Logistic operator at Inköp AB	XXXX-XX-XX

Figure C.4: Backorder



KPI scorecard

PMS location and structure

Supply Chain Dimension	Name of KPI	No. Of KPI in structure of PMS
☐ Reliability ☐ Efficiency ☑ Responsiveness ☐ Sustainability	Unbooked backlog	*On what level in the PMS is the KPI located?* 3.1.2

Definition and purpose

Link to higher level KPI	Linked to strategic objective
☐ KPI is a top level indicator (Strategic KPI) ☑ Operational KPI and related to; Backlog	

Explanation of KPI	Purpose (KPQ)
Amount of orders that SSI has received, but are not confirmed by material suppliers and 3PL.	How many orders do we currently have that are not covered in terms of capacity and delivery?

Calculation and data collection

Formula and unit of KPI

$$Amount\ of\ orders\ that\ has\ been\ received, but\ are\ not\ confirmed\ by\ material\ suppliers\ and\ 3PL$$
= Number of Unbooked backlogs

$$Amount\ of\ orders\ that\ has\ been\ received, but\ are\ not\ confirmed\ by\ material\ suppliers\ and\ 3PL$$
$x\ Quantity\ [ton] for\ each$ = Unbooked backlog [ton]

Target

What is the desirable output of the KPI?

☑ Minimize
☐ Maximize
☐ Specific value;

Source of Data

☑ ERP System (Monitor)
☐ Survey
☑ Order tracking system

Each order and it's quantity in ton from customer should be registered in the ERP system at Inköp AB. When an order is shipped from supplier this should be reported from the 3PL order tracking system into the ERP system as an shipped order. Late orders and not unbooked should be identified in the ERP system.

Level of metric calculation	Intended reporting levels
Which level is the data reporting frequency and calculation conducted at? ☑ Shipment (Per vechicle) ☐ Order ☐ Product Group	*On what level will the data be evaluated and analyzed?* ☐ Shipment (Per vechicle) ☐ Order ☑ Product Group ☑ Supplier ☑ Customer

Reporting and other input

Reporting frequency	Reciever of report	Qualitative input
How often is data evaluated and analyzed? ☐ Daily ☐ Weekly ☑ Monthly ☐ Other	☑ Operative team ☑ Company management ☑ Company board ☐ Suppliers ☐ 3PL ☐ Customer ☐ Other	*Other information that needs to be considered and complements the KPI*

Process owner and responsible department	Release date / Revision
Logistic operator at Inköp AB	XXXX-XX-XX

Figure C.5: Unbooked backlog