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Master Degree Project in Logistics and Transport Management

End-to-end Supply Chain Measurement Framework and Metrics

A case study for COMPANY X

Emma Kritsotakis and Maija Maarni

Supervisor: Rick Middel
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Abstract

As part of the supply chain management, performance measurement has gained a lot of attention from both academic and business environments over the last years. Still, the existing theories on measurement system design and selection of metrics stand insufficient to provide significant support in strategy development, decision-making and performance improvement. The aim of this paper is to propose a specific measurement framework and relevant metrics for Company X to measure the performance of the end-to-end Product X supply chain. Product X supply chain is considered unstable and unreliable, and its performance is poorly measured. The proposed measurement framework is based on a selection of top cited theoretical measurement models and the suitability of metrics is grounded according to data obtained from interviews at Company X (case study). The suggested measurement system supports problem diagnosis and provides the necessary feedback to enable the Company X to take the appropriate corrective measures. As a result, it contributes to improved efficiency and effectiveness of the end-to-end Product X supply chain. Besides the Product X specific measurement framework, which is highly contextual, the suggested theoretical model is applicable to other supply chains within Company X, as well as to supply chains in various industries.

Keywords: supply chain measurement, performance measurement framework, metrics, end-to-end supply chain

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Emma Kritsotakis

Maija Maarni

Abbreviations

ANP = Analytic Network Process

APO = Advanced Planner Optimizer

ASN = Advanced Shipping Notification

BO = Backorders

BSC = Balanced Scorecard

CAPA = Corrective Action and Preventive Action

CH6 = Chlorhexidine digluconate

CM = Contract Manufacturing

CSC = Customer Service Center

CSIO = Customer Service Information Officer

CPM = Complaints per million

CT = Cycle Time

DC = Distribution Center

EDI = Electronic Data Interchange

E2E = End-to-end

EU = European Union

FTC = Freight to Customer

GI = Goods Issue

GR = Goods Receipt

IB = Inbound

IT = Information Technology

KPI = Key Performance Indicator

LT = Lead Time

MHRA = Medicine and Healthcare products Regulatory Agency

MOH = Ministry of Health

MRP = Material Resource Planning

NCN = Non-Conformity Notification

SCOR = Supply Chain Operations Reference

SKU = Stock Keeping Unit

SLA = Service Level Agreement

OB = Outbound

OEE = Overall Equipment Efficiency

OLA = Order Line Availability

OLC = Order Line Completeness

OTC = Order to Cash management

OTIF = On-Time In-Full

QP = Qualified Person

PLIX = Planning Index

PO = Purchase Order

PPMH = Process and Performance Metrics Hierarchy

SC = Supply Chain

SCC = Supply Chain Council

SCOR = Supply Chain Operations Reference

SCP = Supply Chain Planning

SKU = Stock Keeping Unit

SPM = Supplier Performance Measurement

S&OP = Sales and Operations Planning

3PL = Third-Party Logistics provider

TRPS = Transport boxes

TUC = Tied-up Capital

US = United States

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1. Introduction

Among other major trends and alterations, globalization, increased competition and outsourcing have permanently changed the business environment of companies (Chae, 2009). While goals on a company level, such as shortening lead times, cutting down costs and improving quality and service have existed for a long time, more focus has lately been put on effective management of the supply chain (Gunasekaran et al, 2004). Supply chain management is a business philosophy that has enabled companies to achieve and sustain competitive advantage, as well as to improve profitability by satisfying customers effectively and efficiently (Chan & Qi, 2003a). This is done through enhanced inter- and intra-firm relationships and by increasing visibility of the end-to-end (E2E) supply chain (Shepherd & Günther, 2006; Simatupang et al, 2004). Companies have realized that working together as a team across the E2E supply chain, handling activities as part of a supply chain, not independently and sharing common goals and strategies bring out benefits to all members involved (Gunasekaran et al, 2004; Simatupang et al, 2004). As a result, the scope of supply chain management has expanded and hence, in today's market it is supply chains that compete with each other, not companies (Agarwal et al, 2006; Chan & Qi, 2003b).

In order to manage the supply chain there is a need to measure its performance. "*Performance measurement is defined as the process of quantifying effectiveness and efficiency in action*" (Neely et al, 1995, p.80). It is a management tool that enables performance improvement, efficient resource allocation, revision of business goals and process re-engineering through performance monitoring, progress disclosure, problem diagnosis and enhanced motivation and communication (Chan & Qi, 2003b). With the evolution of supply chain management, a huge selection of articles dealing with this topic both in theory and practice has been published. On the other hand, supply chain performance measurement has not received adequate attention from researchers and practitioners (Beamon, 1999; Gunasekaran et al, 2004). There are various articles addressing theories and practices of performance measurement, but there is very little research on measurement system design and selection of metrics (Chan & Qi, 2003a). That is, there are no clear, practical guidelines for how to develop a measurement framework and how to find the most appropriate metrics (Chae, 2009). This is a challenge facing most companies and one of them is the Company X.

1.1 Background of the Company X

Company X is one of the world's leading manufacturers of single-use surgical and wound care products and service providers in the field of healthcare. The company is service-oriented and customer satisfaction is emphasized as a top priority. The products the company sells include surgical gloves, face masks, bandages and antiseptic solutions among others (Company X, 2014).

Antiseptics are antimicrobial substances used in health care to avoid skin infections and to help in ensuring clean surgeries. The antiseptic solutions compose a product line Y. The Product X range includes aqueous scrubs, alcohol-based rubs and concentrates, which can be diluted for a variety of different usages. They are packed in bottles/containers, sachets with/without wipes and ampoules. The antiseptic portfolio is classified in biocides, pharmaceuticals and medical devices and there are two main products within this category. The Product X target market varies geographically, but Company X mainly focuses on two regions: Europe and the United States (US). Country A and central Europe together with the US represent 82% of the total sales of antiseptics at the Company X (Internal company report on antiseptics, 2014). Product X is developed for the European market, while product Y for the US market. Company X does not produce antiseptics itself; instead the company purchases antiseptics as finished products through contract manufacturing.

1.2 Problem statement

Throughout the years Company X has measured performance of the Product X supply chain mostly internally and has adopted metrics partly randomly. Overall, Company X does not have a clear performance measurement framework for Product X, neither consistent measurement practices, nor regular revision of metrics. Therefore, the current measurement system and metrics have not always proven to be sufficient. Further, some dimensions of performance, like flexibility, adaptability and responsiveness are currently hardly being measured at all. The company is also lacking metrics in measuring certain segments like inbound and outbound logistics. For example, lead times between suppliers and warehouses or between warehouses and customers are not measured at the moment at the Product X supply chain level.

Company X is experiencing many challenges in a number of supply chains. Product X supply chain is one of the most problematic ones, not least because of the tightly regulated health care industry. In general, the company is not very experienced in the field of pharmaceuticals, which is the general group Product X is categorized into. The emphasis has historically been on medical devices and Company X is therefore to some extent lacking the required know-how to understand, manage and measure the E2E Product X supply chain. More specifically, the Product X supply chain is currently perceived as unstable and unreliable. Even though most of the time Company X masters successfully the processes of the Product X supply chain and reaches its financial objectives, the company is facing several problems within production, quality, warehousing and transportation of the products among others. These have led to high costs for the company and huge backlogs with long lead times to its customers. Since Company X lacks a complete measurement system to follow-up performance of the E2E Product X supply chain it is very challenging to find out the root causes to these problems.

1.3 Purpose of research

The purpose of the thesis work is to develop a specific measurement framework and to propose suitable metrics for the E2E Product X supply chain. In order to do so the E2E Product X supply chain processes have to be reviewed and the current E2E Product X supply chain measurement system has to be analyzed, determining whether it is measured correctly, if the relevant metrics are being used and what kind of problems and challenges occur concerning the measurement.

1.4 Research question

Which supply chain performance measurement framework and metrics are relevant for Company X in measuring the performance of the end-to-end Product X supply chain?

1.5 Expected outcome

The expected outcome of the research is the specific performance measurement framework for the E2E Product X supply chain, as well as relevant metrics. The aim is not to use an existing model as such, but to develop a new framework based on theoretical discussions and empirical findings. Suggested metrics are adapted from existing theoretical models and from the current

Company X measurement regime. The proposed measurement framework is targeted to enhance the E2E Product X supply chain planning and will help Company X to find the root reasons to the problems causing unstable and unreliable deliveries. In this way the company will be able to improve the Product X supply chain performance and to make the supply chain more constant and trustworthy. This will in turn lead to increased efficiency and effectiveness of the Product X supply chain, and improved outcome (customer satisfaction). Moreover, the proposed theoretical framework will serve as a measurement template, which in the future can possibly be generalized and applied to other Company X supply chains, as well as to supply chain in other industries.

1.6 Research limitations

Due to the time restrictions and in order to achieve the research goal, the subject under investigation is narrowed down. That is, the research is focused solely on one product category supply chain, namely the Product X supply chain. Only the Product X product line will be investigated, as just one geographical area, Europe is incorporated. As a simplification Product X is referred as Product X throughout the text. E2E Product X supply chain in this research context is the flow from Company Y to distributor/end-customers. Further, only two particular flows are being reviewed. These are the flows starting from Company Y and ending at the end-customers (hospitals) in the Country A market and at the distributor, Company Z, in the Country B market. The reasoning behind the choice of specifically these two flows is their share of the total Product X product sales and their diverse natures. They make up 50% of the total Product X sales and the flows are somewhat different (Internal company report on sales, 2013). Therefore, it is interesting for Company X to explore possible divergences and similarities in their measurement. The proposed measurement framework will however be applicable to all types of market flows for Product X. This research will not evaluate the current processes or propose improvements in this area. Moreover, the thesis will not study the implementation of the proposed measurement system and metrics, which is a challenge as such.

1.7 Outline

The following chapter consists of the literature review and the theoretical framework. Literature review introduces the reader to the definitions of measurement system and metric, argues why and how to measure and discusses measurement design criteria and the most common measurement challenges. Furthermore, a selection of five measurement frameworks and their specific metrics are reviewed; advantages and disadvantages of each framework are discussed and compared with each other. The outcome of weighing the pros and cons of each model is the basis for the theoretical framework, which is introduced at the end of the literature review part. The third chapter presents the research design, research strategy, methods of data collection, validity and reliability of the paper. The next chapter consists of the empirical part, where Product X supply chain is discussed under a more detailed context. The two specific flows under investigation are unfolded, and current measurement practices are presented and summarized into a table. Having compared the gaps between the existing and the theoretical measurement frameworks and metrics, the fifth chapter contains the layout of the final framework. Moreover, measurement related challenges that Company X is experiencing are analyzed in this chapter. The paper concludes with the research findings, as well as recommendations for Company X and suggestions for further research.

2. Literature review

"Supply chain is described as a chain linking each element from customer and supplier through manufacturing and services so that flow of material, money and information can be effectively managed to meet the business requirement" (Stevens, 1989, p.4). Managing the E2E supply chain effectively entails cooperation and coordination between all supply chain members. Companies strive to promote higher integration of organizations by developing cross-functional teams, forming supplier partnerships and strategic alliances with upstream and downstream partners, and sharing information across the E2E supply chain. The focus is on improving product quality and customer service level to meet customer requirements. A higher customer service level can be reached for example through product customization and quick response (Chan & Qi, 2003a). Additionally, customer requirements need to be satisfied efficiently (Chan & Qi, 2003b). To ensure and improve profitability, costs and inventory level need to be reduced and lead times shortened.

In order to manage the E2E supply chain effectively and efficiently the performance has to be measured. Supply chain performance measurement and metrics are a core concern for many companies which cannot be neglected, since what cannot be measured cannot be improved (SCC, 2010). However, little has been done when it comes to empirical analysis and case studies in the field of measurement (Gunasekaran et al, 2004). That is, there are very few practical and concrete precepts on how to measure the E2E supply chain performance and what metrics to use (Gunasekaran & Kobu, 2007, Shepherd & Günther, 2006, Gunasekaran et al, 2001; Chae, 2009). Overall, it is found that many firms are adopting metrics mostly internally and have failed to develop metrics that would measure integrated supply chain and hence maximize its efficiency and effectiveness (Chae, 2009; Gunasekaran et al, 2004).

2.1 Measures, metrics and key performance indicators

The existing definitions for the terms measure, metric and KPI are controversial and there are no explicit meanings that have been unanimously accepted, neither from the academic nor the business world. These definitions are very often mixed and there are many of those who argue that they constitute different terminologies for the same thing. Especially, the terms measure and metric are frequently used interchangeably, as the difference between them is subtle. According to Gunasekaran & Kobu (2007), the term metric refers to the definition of the measure and stipulates how and by whom it is calculated as well as from where the data is gathered. In this paper a measure is defined as anything that can be measured from various aspects, whereas a metric is a comparison of two or more measures that evaluates a specific aspect. Both consist of a number and a numeric unit. For example a measure could be 100 customers and a metric another "figure" comparing measures of 100, 110 and 120 customers, stipulating that the amount of customers is growing. Hence, in this thesis the main difference between a measure and a metric is that a measure is just an indicator, a snapshot of a situation, whereas a metric gives more information about the development and whether values measured are good or bad. KPIs, on the other hand, are defined as metrics selected to measure performance within a specific business organization or industry context using set value targets (Forman, 2012). They compare metrics to expected/targeted results and are derived from the company's strategy. A metric has to have strategic approach in order to be considered as a KPI. Hence, a KPI is a metric, but a metric is not always a KPI.

2.2 End-to-end supply chain measurement and metrics

Metrics are divided into two categories: quantitative (financial) and qualitative (non-financial) (Beamon, 1998). Traditional, financial performance metrics are unquestionably no longer valid alone in measuring the effectiveness of the supply chain. They are applicable in measuring the value of simple supply chain applications, whereas modern supply chain applications are far from that. Financial metrics play an important role in measuring strategic decision and external reporting, while non-financial metrics are more suitable in measuring day-to-day control of operations (Gunasekaran et al, 2004). Disadvantage of financial metrics is their internal, inward-looking nature and the fact that they are based on historical data (Gopal & Thakkar, 2012). On the contrary, measuring intangibles and non-financial factors pose a great challenge in the current knowledge economy (Gunasekaran & Kobu, 2007).

Traditionally many metrics, such as hours worked and purchasing prices have aimed at minimizing costs. This approach, however, fails to take into account total supply chain costs and hence its validity is questionable (Collins & Harris, 1992). In general, non-financial metrics have gained attention on the cost of financial metrics. For instance, Gunasekaran et al (2001) argue that fulfillment time and delivery performance are the central metrics for an effective supply chain. Zhang et al (2011) suggest that reliability assurance and the level of supply chain cooperation are important performance metrics. Beamon (1999) adds customer satisfaction, information flow, supplier performance and risk management to the list of important qualitative metrics. On the other hand, a study of Said et al (2003) revealed that combination of financial and non-financial metrics results in better returns on assets and hence better profitability.

Neely et al (1995) describe performance measurement as a process of quantifying the efficiency and effectiveness of various activities. This is also the core intention of the E2E supply chain measurement system (Gunasekaran et al, 2001; Chae, 2009); to reveal the effectiveness of the supply chain and spotlight needs for development (Chan & Qi, 2003a). In fact, performance measurement goes well beyond quantification and accounting and takes a holistic system perspective. Chan & Qi (2003a) state that *"it is supposed to contribute much more to business management and performance improvement in the various industries"* (p.180). Moreover, the supply chain measurement system is more than just a set of distinctive metrics. It is an integrative, economical and compatible system measuring the performance of the total supply chain, responsible for assigning value-added metrics to each process (Gopal & Thakkar, 2012).

2.2.1 Why to measure?

Measurement sets the ground for meeting quality, speed, dependability, flexibility and cost objectives and enhances continuous improvement by determining future courses of action. On the other hand, when it comes to performance efficiency and effectiveness, the measurement and monitoring reveal gaps between planning and execution in the supply chain by identifying key issues or problem areas (Gunasekaran et al, 2004; Chan & Qi, 2003b). These gaps exist due to uncertainty and unexpected events, especially at the downstream end of the supply chain. They can never be fully removed, but can be successfully managed and controlled (Chae, 2009). Overall, the purpose of measuring supply chain performance is to identify if customer demand is met, understand and improve business processes, ensure the objectivity of decision-making and make sure the planned amendments really took place (Gunasekaran & Kobu, 2007; Chan & Qi, 2003b). Measurement gives important information about performance, progress and improvements and makes intra-supply chain communication easier via common metrics.

The growth and development of E2E supply chains are driven by internal and external reasons. Companies are keen to reduce uncertainty and enhance the control of supply and distribution channels. The motives are financial and operational, aiming at reduced total costs and inventories, increased information sharing, improved customer service levels and technological innovation. External factors, such as globalization, information technology, governmental regulations and environmental concerns drive companies to cooperate and integrate their supply chains (Gunasekaran et al, 2004). Well-structured and motivated performance metrics facilitate a more open and transparent communication between people leading to enhanced cooperation and improved organizational integration (Gunasekaran & Kobu, 2007).

2.2.2 How to measure?

Measurement of supply chain performance requires that core processes and activities are first identified and confined, followed by determining the relevant metrics (Chae, 2009). Once the processes are mapped and suitable metrics identified, it is possible to make improvements that enhance profitability and end-customer value maximization across the entire supply chain. *"A supply chain should be viewed as one single entity and managed as a whole"* (Chan & Qi, 2003b, p. 181). Hence, an integrated performance measurement system should be developed in order to support a compound value chain and assess supply chain performance along the supply chain channel. Additionally, processes and metrics should all be aligned towards mutual goals. This entails that each member-party of the supply chain takes part in developing the metrics, composing the supply chain performance measurement system and is committed to the common goals (Gunasekaran et al, 2004).

There is a need to develop a specific measurement framework and find individual parameters affecting the core business processes of the supply chain that add value to customers and reflect companies' strategies. Management is faced with a lot of questions. What to measure? How to measure? Which metrics to use and how to integrate individual metrics into a measurement system? How to analyze the performance of the supply chain according to metrics? How often do metrics need to be re-evaluated? There are some similarities on how supply chain management can be measured and which criteria to use. Generally, a set of specifications can be utilized to control if the output meets company's goals and expectations. This is done by defining relatively fixed performance parameters (Gunasekaran et al, 2004). The parameter values are used in order to make a comparison between the planned goals and strategy and how the execution has been carried-out. In case a difference is detected between those two values, the root causes are identified and measures taken to improve the supply chain performance (Gunasekaran et al, 2004).

Some of the commonly applied parameters are cost, time, quality and flexibility (Shepherd & Günther, 2006; Gunasekaran & Kobu, 2007). Traditionally, the cost approach is widely used due to its simplicity and quantitative nature. However, even if the organization is very cost effective it might have poor customer service level, long response time and rigid adaptability. Beamon (1999) suggests that time, resource utilization, output and flexibility should be the key areas under interest in measuring the performance. Yet, the role of flexibility and adaptability to changes has increased since today's global market environment is characterized by agility, high variation in demand and fast changing consumer preferences (Gunasekaran & Kobu, 2007). Uncertainty about the demand requires respectively adaptable and agile supply chains (Agarwal et al, 2006). Quality and time metrics also play an important role. The recent trend has also been to select green metrics to enhance the sustainability of the supply chain (Gopal & Thakkar, 2012).

2.2.3 Measurement framework design criteria

In the academic literature there are various measurement systems taking different approaches and suggesting diverse metrics. Design criteria seem to be very similar; a suitable measurement system should be practical, easy to measure, reliable and not to include too many metrics (Gunasekaran & Kobu, 2007; Chae, 2009). It should include a balanced set of metrics, consisting of those most suitable for the supply chain context in order to provide a clear view of the organizational performance (Chan & Qi, 2003a). A general rule tends to be that "less is better" (Chae, 2009). There should be a short list of metrics solely consisting of those which are the absolute necessary so as to successfully monitor the performance of the supply chain (Chae, 2009; Bhagwat, 2007). Metrics, as well as roles and responsibilities of different members and teams, should be clearly defined and communicated across the supply chain in order to enhance optimization of the measurement process (Chae, 2009).

Additionally, the performance measurement model should be transparent, simplified and systematically organized, as this will enhance communication and support in grasping the business objectives. It should be possible to get feedback for various activities and unambiguous data from operations, helping supply chain managers at different levels to understand and improve performance, reveal effectiveness of strategies and identify opportunities (Chan & Qi, 2003b). According to Chan & Qi (2003a), the supply chain measurement system should incorporate a holistic view and go over organizational boundaries, assessing integrated processes, not individual functions. It should be aligned with the company's strategy; efficient, lean and cost-conscious or responsive and agile with high customer service level. Further, the system should be dynamic and balanced. It should evolve over time and include both financial and non-financial metrics. A well-planned system should enable the management to drill-down in specific areas to find the distinct issues that need to be improved (Lapide, 2000).

These criteria are good to bear in mind when developing a new measurement framework. Which metrics are the most appropriate ones is, as already mentioned, contextual and varies from supply chain to supply chain (Chan & Qi, 2003a). Hence, the choice of metrics depends, besides design criteria, on the chosen strategy, goals and objectives, type of business, market environment and technological capabilities (Gunasekaran & Kobu, 2007).

2.2.4 Measurement challenges

"The complexity of practical supply chain shapes the difficulties in mapping supply chain structure, managing integrative relationships and measuring the systems performance" (Chan & Qi, 2003b, p. 189). Gopal & Thakkar (2012) mention trust, communication, control, objectives, information systems and the definition of customer value as the most often cited claims. There are also common difficulties in designing the supply chain performance measurement system. Since supply chains are more and more fragmented, the need for continuous improvement is evident. This poses a challenge, as it requires the identification of the suitable key metrics.

Finding the relevant metrics for the entire supply chain is a complicated procedure and many companies fail to apply metrics that fully integrate their supply chains (Chae, 2009; Chan & Qi, 2003b). Managers confront a situation where they are confused by a wide variety of metrics and KPIs, that mainly focus on measuring performance of some specific aspects at organizational level instead of the overall supply chain system. The managers often lack system thinking and good understanding of the interdependencies and relationships between the various parameters in the supply chain system. Hence, the existing performance metrics are frequently criticized as being disconnected from the company's strategy and too isolated (Chan & Qi, 2003a).

Other typical pitfalls are the lack of applicable and relevant metrics, as well as the use of too many metrics. Changing qualitative variables into measurable quantitative parameters is a very demanding job and areas such as customer satisfaction, collaboration of buyers and suppliers, information sharing and flexibility are not easy to measure. When it comes to the number of metrics it is characteristic for many companies to keep adding metrics to the already existing ones, influenced by advice or suggestions of employees and consultants. Eventually, it becomes hard for the supply chain members to understand all the metrics and hence focus, transparency and objectivity become blurred (Gunasekaran et al, 2001; Bhagwat, 2007).

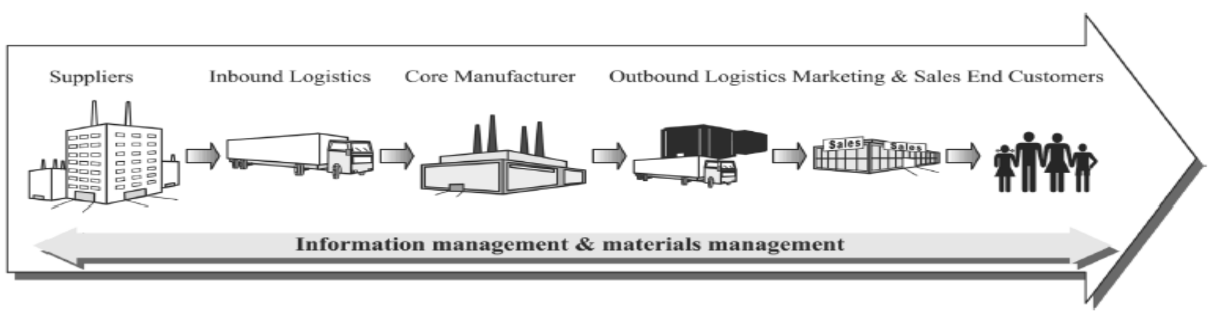
2.3 Measurement frameworks

There is a limited amount of articles dealing with practical measurement frameworks and concrete metrics for evaluating performance of supply chains. Most of the research papers are rather descriptive and there are not very many empirical research results or case studies of finding the most feasible measurement method and metrics. How the problem should be approached is quite controversial. This illustrates that the need for additional research on performance metrics in the global environment and in the supply chain context is evident. According to Basu (2001) the metrics could be divided in five categories measuring external, consumer, value-based, competition, network performance and intellectual capital factors. Other studies suggest that companies adopting high delivery performance, flexibility and logistics cost control are the ones performing the best (Steward, 1995). According to Beamon (1999) many supply chains use costs as their primary metric, which is often inconsistent with the company's strategy and goals.

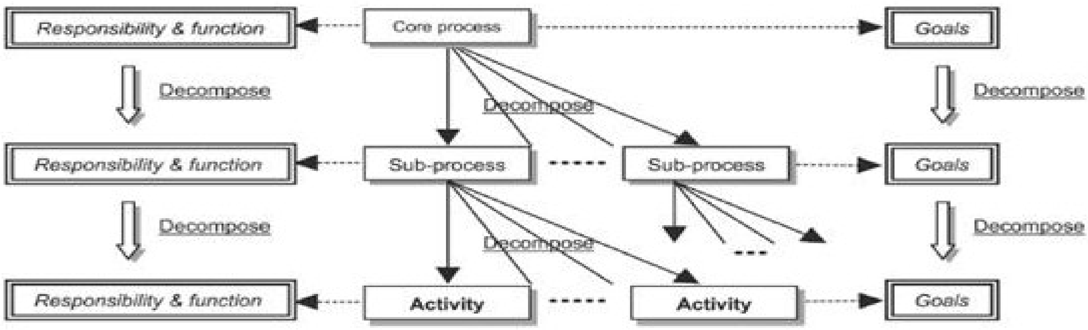
An overview of five of the most cited supply chain measurement frameworks in literature follows, along with some examples of their proposed metrics.

2.3.1 Chan and Qi model

The model of Chan & Qi (2003a) is an example of process-based frameworks. The researchers developed a cross-organizational supply chain performance measurement model taking a holistic system-thinking perspective. Chan & Qi (2003b) define a process as a set of integrated activities aimed at performing specific functions and identified six key processes that are linked together; supplier, inbound logistics, manufacturing, outbound logistics, marketing and sales and end customer (Picture 1). These main processes can be decomposed into subprocesses and further into detailed activities. For instance, inbound logistics can be split into purchasing, transportation, receiving & inspection, handling & storing and supply base management. Transportation for example can be further decomposed into transport cost, transport productivity, transport flexibility and facility utilization. The measurement framework is a hierarchy of a supply chain model composed by these key processes, subprocesses and activities (Picture 2). *"The performance of each process is the aggregated results of the performance of all its lower hierarchy activities and subprocesses"* (Chan & Qi, 2003b, p. 183). Hence, by assessing the subprocesses and activities in the lower hierarchies one can gain understanding of how they affect the top level core processes.

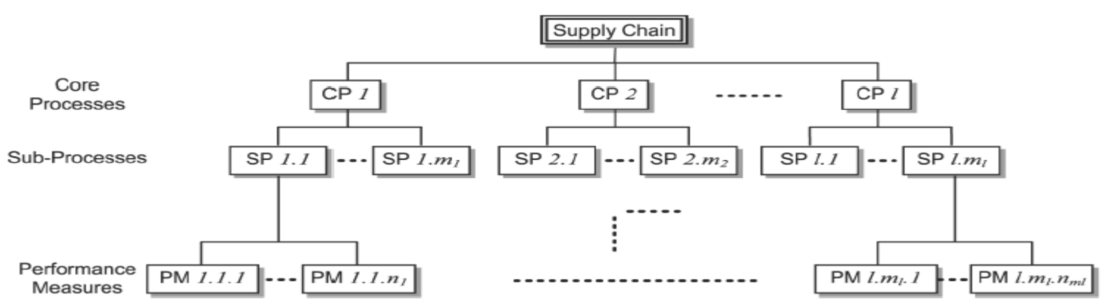


Picture 1: *Key Supply Chain Processes (Chan & Qi, 2003b)*



Picture 2: *Supply Chain Process Model (Chan & Qi, 2003b)*

Chan & Qi (2003a) identified selecting the suitable metrics for each process and subprocess as the next step. After that, they suggest to group the associated metrics into the hierarchy of the processes building up a process and performance metrics hierarchy (PPMH) measurement framework (Picture 3). Chan & Qi (2003b) suggest using the board of performance metrics that is included in the performance of activity method. The metrics board consists of a selection of qualitative and quantitative metrics that cover both the input and output aspects. Each metric represents one of the dimensions of activity performance and they are classified in hard and soft ones. Hard metrics consists of cost, time, capacity, productivity and utilization; they are tangible and hence easy to collect and measure. Soft metrics include capability (effectiveness, reliability, availability, flexibility) and outcome; they are intangible and therefore not as easy to measure directly. Chan & Qi (2003a) state that not all dimensions of any activity performance have to be present in each process. It is the task of the management to choose the most relevant ones according to the company's strategy. An example from a section of the PPMH measurement framework is available in Appendix 1.



Picture 3: *Process and Performance Metrics Hierarchy Measurement Framework (Chan & Qi, 2003a)*

2.3.2 SCOR model

The Supply Chain Operations Reference (SCOR) model is another process-based framework that has become widely known within the area of supply chain performance measurement (Chae, 2009). SCOR is presumed to become a standard framework that enables strategic planning and measuring of supply chains (Huan et al, 2004). Research on supply chain measurement has produced various operational and design models, but a strategic approach capturing the view of the entire supply chain is scarce. SCOR-model aims to fill this gap and attempts to help strategic decision-making. According to Huan et al (2004), it integrates process reengineering, benchmarking, and process measurement into the same framework. The model is developed by the Supply Chain Council (SCC) and is based on five main processes; plan-source-make-deliver-return. It starts with the top level main processes, modeling the overall activities. These are followed by subprocesses and activities that are subordinated to the main processes. The processes are divided into three levels; the top level dealing with the above mentioned process types, the middle configuration level describing process categories and the lowest level considering process elements. Second and third level processes are the supportive foundation for the main processes (Huan et al, 2004). For instance, the main process plan is decomposed into make-to-stock, make-to-order and engineer-to-order, and as an example make-to-order further split into specific activities, such as schedule production activities, issue product, produce and test, package, stage, dispose waste and release product. SCOR processes extend from suppliers' supplier to customers' customer (SCC, 2010).

The performance section of the SCOR model consists of two elements; performance attributes and metrics. The top level introduces twelve performance metrics, which are categorized under five performance attributes: reliability, responsiveness, agility, cost and asset management. Supply chain scorecard should include at least one metric from each of these categories (SCC, 2010):

- Reliability reflects the ability to perform as expected and the typical metrics include on-time, the right quantity, and the right quality. At the top level in the SCOR model the metric is perfect order fulfillment.
- Responsiveness measures how fast the company is performing tasks. Typical metrics are various cycle time measures, such as source cycle time, make cycle time and deliver

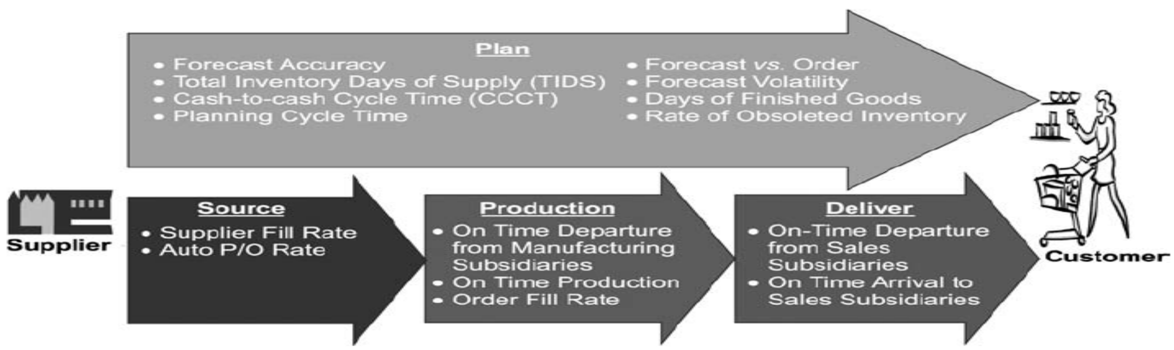
cycle time. The top level metric in the SCOR model is order fulfillment cycle time.

- Agility tells about the ability to respond to external changes, such as variations in demand, changes in political or financial business environment or supplier base. The main SCOR model metrics include flexibility, adaptability and value at risk.
- Cost of operating the processes is important for all the companies and includes for example management costs, labor costs, transportation costs and material costs. The top level SCOR model metrics include cost of goods sold and supply chain management cost.
- Asset management efficiency reflects the ability to efficiently utilize assets and resources. The common aim is to minimize inventory and to find the optimal solution between insourcing and outsourcing. Typical metrics consist of capacity utilization and inventory days of supply. SCOR model level one metrics include cash-to-cash cycle time, return on fixed assets and return on working capital.

The level one metrics are then divided into level two metrics. For instance, perfect order fulfillment is divided into four subgroups; percentage of orders delivered in full, delivery performance to customer commit date, documentation accuracy and perfect condition. Thereafter, each of level two metrics is decomposed into level three metrics. For instance, percentage of orders delivered in full is split into delivery item accuracy and delivery quantity accuracy. Level one and two metrics keep the management focused while level three metrics diagnose variations in performance against plan. Processes and metrics are combined together to analyze and measure the performance of the overall supply chain. The SCOR model framework and metrics are available in Appendix 2.

2.3.3 Chae framework

Chae (2009) takes a more practical approach to supply chain performance measurement and argues that companies can benefit from having selected metrics layered or hierarchically organized. Using the four meta-level processes of the SCOR model, plan-source-make-deliver, as the basis of his framework, he suggests a two-layer model and hierarchically groups metrics into primary and secondary ones. The primary ones represent the overall supply chain performance and are usually monitored by the top and middle managers, whereas the secondary ones give more insights into details diagnosing the elaborate reasons for underperformance of the primary metrics. For instance, in the planning phase the total inventory days of supply would be a primary measure. Instead of minimizing the inventory at the company level it should be minimized at the supply chain level. Secondary metrics would then include more detailed data about inventories, such as days of finished goods at different subsidiaries (sales, manufacturing) and the rate of obsolete inventories. The first layer of the measurement framework consists of the planning process and the relevant primary and secondary metrics, the second one of sourcing, making, and delivering and their respective metrics. The framework layout enables assessment and evaluation of how accurate planning is and how well sourcing, production and delivery execution are carried-out. The picture below (Picture 4) depicts Chae's model with the proposed primary and secondary metrics for each process.



Picture 4: *Process and Hierarchy Measurement Framework (Chae, 2009)*

2.3.4 Gunasekaran et al framework

Another option is to look at the hierarchy and the level of decision-making. Gunasekaran et al (2001) present a framework for measuring the strategic, tactical, and operational level of performance in the supply chain. They identify metrics in the context of the main phases of the supply chain, plan-source-make-deliver, and then hierarchically classify them into strategic, tactical and operational ones, illustrating the level of management authority and responsibility for performance. The metrics at each level provide valuable feedback and influence management decisions on all layers; top level, mid-level and low level. The metrics are grouped in cells at the intersection of supply chain phase and the level of decision-making. For example, supplier delivery performance (supply phase) falls under the tactical decision making. It is a helpful metric in assessing performance of mid-level managers, since they are the ones responsible for all sourcing activities. Additionally, the metrics of each group-category are listed in order of importance. Some metrics are perceived as relevant for more than one management level and can hence belong to several metric categories (Gunasekaran et al, 2004). According to Gunasekaran & Kobu (2007), most of the metrics on strategic level are based on financial measures, while tactical and operational levels employ more non-financial measures. The table (Picture 5) below reveals the metrics proposed by Gunasekaran et al (2004) for each supply chain activity and level of decision-making respectively.

Supply chain performance metrics framework

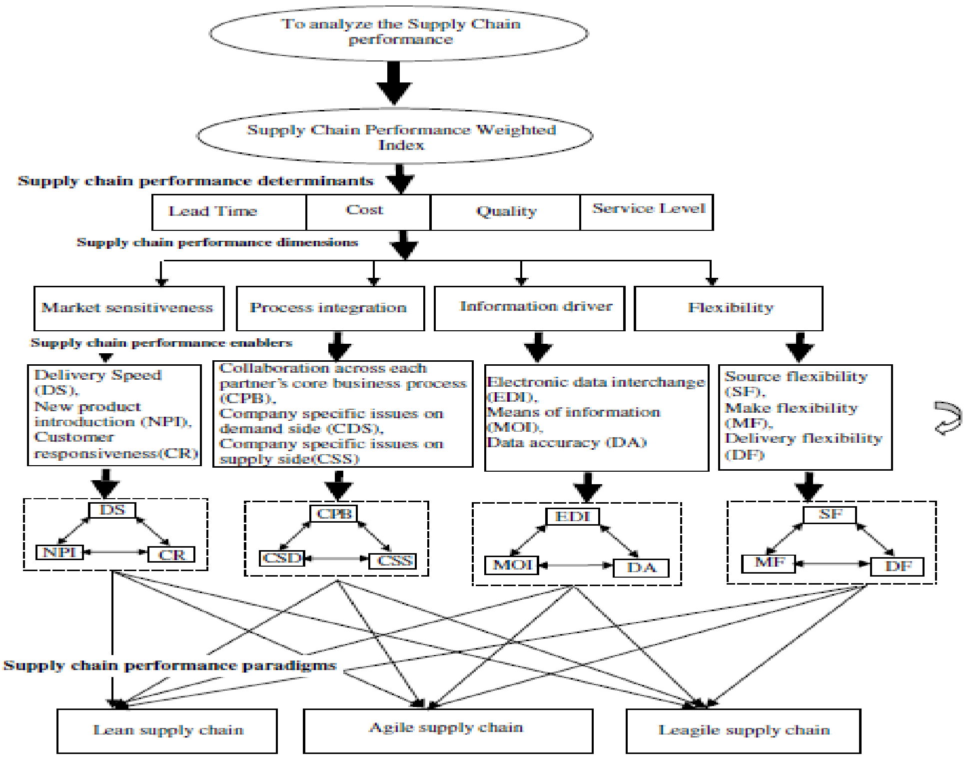
Supply chain activity/ process	Strategic	Tactical	Operational
Plan	Level of customer perceived value of product, Variances against budget, Order lead time, Information processing cost, Net profit Vs productivity ratio, Total cycle time, Total cash flow time, Product development cycle time	Customer query time, Product development cycle time, Accuracy of forecasting techniques, Planning process cycle time, Order entry methods, Human resource productivity	Order entry methods, Human resource productivity
Source		Supplier delivery performance, supplier leadtime against industry norm, supplier pricing against market, Efficiency of purchase order cycle time, Efficiency of cash flow method, Supplier booking in procedures	Efficiency of purchase order cycle time, Supplier pricing against market
Make/ Assemble	Range of products and services	Percentage of defects, Cost per operation hour, Capacity utilization, Utilization of economic order quantity	Percentage of Defects, Cost per operation hour, Human resource productivity index
Deliver	Flexibility of service system to meet customer needs, Effectiveness of enterprise distribution planning schedule	Flexibility of service system to meet customer needs, Effectiveness of enterprise distribution planning schedule, Effectiveness of delivery invoice methods, Percentage of finished goods in transit, Delivery reliability performance	Quality of delivered goods, On time delivery of goods, Effectiveness of delivery invoice methods, Number of faultless delivery notes invoiced, Percentage of urgent deliveries, Information richness in carrying out delivery, Delivery reliability performance

Picture 5: *Process and Level of Management Measurement Framework (Gunasekaran et al, 2004)*

2.3.5 Lean versus agile framework

Lately, the responsiveness of the supply chain has gained a lot of attention on the cost of efficiency. Emphasis has changed from leanness to agility. Leanness is a philosophy that strives to reduce waste and make processes as cost-efficient as possible. It is characterized by continuous development and works the best in the market situation with high volumes, low variation and easiness to forecast. Therefore, leanness is not the best solution to answer the fast-changing customer needs and uncertain market environment. Instead, agility has appeared as a common approach in the supply chain context. Agile supply chains are characterized by high volatile market demand, high product variety and short product life cycle (Agarwal et al, 2006). Christopher and Towill (2001) define quality, cost, lead time and service level as the most suitable supply chain performance dimensions. For agile supply chains the service level is the market winner and the others market qualifiers, while for the lean supply chain cost is a market winner. Leagile supply chain on the other hand combines both paradigms and targets cost efficiency at the upstream end and high service level at the downstream end of the supply chain.

Agarwal et al (2006) modeled a framework for lean, leagile and agile supply chains using the Analytic Network Process (ANP) approach (Picture 6). This enables the measurement of various performance dimensions on components, such as timely response to meet the customer demand, and evaluation of how performance determinants influence one another. In ANP the key supply chain performance determinants are similarly lead time, cost, quality and service level. These are measured by four performance dimensions: market sensitiveness, information, process integration and flexibility. Market sensitiveness measures how quickly the supply chain responses to demand and is characterized by six metrics: delivery speed, delivery reliability, new product introduction, new product development time, manufacturing lead time and customer responsiveness. Information variable estimates how well the supply chain uses information technology to exchange data between buyers and suppliers. Process integration evaluates the level of collaboration between purchasers and suppliers, the use of common systems and level of information sharing. Collaboration across each partner's core business process for instance is one of the main enablers of process integration. Lastly, flexibility assesses the readiness and degree of the company to adjust speed and volumes of the supply chain after changes in market demand. The ANP model helps the strategic management to select the most relevant paradigm for supply chain measurement in a complex environment. The criteria and performance attributes used to assess the performance are in line with the strategy and requirements of the supply chain. Further, the model takes into consideration both qualitative and quantitative characteristics (Agarwal et al, 2006).



Picture 6: *Analytic Network Process Measurement Framework (Agarwal et al., 2006)*

2.4 Comparison of the various models

Most of the various measurement systems presented above are based on the four main processes; plan-source-make-deliver. Researchers argue that a process-based approach enhances supply chain integration and cross-organizational optimization, since it blurs organizational and departmental boundaries and enables process measurement, benchmarking and process re-engineering according to noticed improvement demands (Chan & Qi, 2003a; Chan & Qi, 2003b). This high-level view of supply chain management processes is believed to be very useful for identifying potential metrics (Chae, 2009). On the other hand, some researchers argue that the best approach is one that is based on the four main processes, but also organizes metrics in layers or hierarchies (Gunasekaran et al, 2004; Chae, 2009). In this way companies are further benefited as supply chain performance is more closely monitored and controlled by the appropriate management levels. This is something that is missing from the solely process-based models.

In particular, Gunasekaran et al (2004) suggest that by classifying the metrics hierarchically into strategic, tactical and operational levels, supply chain performance is better assessed and fair decisions are made. However, this framework can be regarded only as a starting point for individual companies. It suggests specific metrics, which may not be in line with their unique business strategies, and hence need to be re-adjusted accordingly. Moreover, the rated importance of the metrics proposed in this model might not apply to all supply chains in all industries, as it is based on a small sample and cannot be generalized to all the supply chains (Gunasekaran et al, 2004).

As discussed earlier, the SCOR model is one of the most discussed models in the field of exploring supply chain performance measurement and metrics, and one of the most accepted ones worldwide (Huan et al, 2004; SCC, 2010). SCOR is a process-focused model that assists the strategic management by improving the alignment according to the marketplace, and easing the communication between various levels and supply chain members (SCC, 2010). It evaluates performance rapidly, and clearly identifies performance gaps, as it comes to develop relevant metrics for the entire supply chain (Chae, 2009). It is a valuable tool for the management to design and set-up a measurement system for an efficient supply chain (Huan et al, 2004). However, Huan et al (2004) suggest further improvement into the SCOR model. According to them, change management and supply chain integration should be taken into consideration. Moreover, SCOR does not take all processes and activities into account, for instance it does not describe sales and marketing or product development, and it assumes, but does not address in specific quality, information technology or administration (SCC, 2010).

Chae (2009) grounds his measurement framework on the SCOR model and takes a practical approach recommending metrics that are classified in two layers: primary and secondary. The performance measurement framework he suggests is easy and fast to implement, as it focuses on a short list of metrics, those that are the most essential for a firm’s operations management, customer service and financial viability. Nevertheless, Chae’s (2009) measurement model is criticized for being too simple and having limited scope. Thus, it is quite controversial whether it can be applied to all supply chains in different industries.

Similarly to the SCOR model, Chan & Qi (2003a) take a process-based approach. The measurement system they suggest is advantageous as it facilitates a deep insight of the process performance by applying metrics at each level of activity. This provides more visual information about the effectiveness of the management and enables monitoring and efficient resource allocation, as well as process re-designs. Moreover, the model develops a balanced view of the performance by applying multidimensional metrics that allow benchmarking within same performance dimensions (Chan & Qi, 2003a; Chan & Qi, 2003b). Its opponents claim that the model is too functional and does not pay enough attention to the overall company strategy and missions. Thus, the measurement and metrics should not only be linked to the operational targets, but rather to the more general company goals. Additionally, the authors themselves discuss the difficulty to aggregate results as a drawback of their model (Chan & Qi, 2003a).

Lastly, Agarwal et al (2006) take a more modern view of performance measurement and propose the ANP model. This is a measurement system that helps supply chain managers select the most relevant paradigm for supply chain performance measurement choosing between lean, agile and leagile supply chains. As a result, they are able to make strategic decisions that are essential for growth and survival of supply chains. The proposed framework is designed exclusively for a supply chain in fast moving consumer goods business and hence cannot, as such, be generalized to other product categories or services. Furthermore, the ANP model is characterized as cumbersome and difficult to apply in practice, as the relevant metrics might not be very easy to find and there is a challenge of subjectivity, since when using the ANP system all the parameters need to be weighed (Agarwal et al, 2006). However, some of the metrics suggested by the model can be applied across the supply chains to evaluate the agility and responsiveness.

To sum up, there are differences detected in approach emphasis between the discussed performance measurement frameworks, even though almost all of them apply features of both process-based and hierarchical models. Performance parameters and core metrics are on the contrary very similar in all measurement systems. Cost, time, flexibility and outcome are found to be the core performance parameters in these models. Differences and similarities, together with advantages and disadvantages of each performance measurement framework are summarized into the table below providing a more visual presentation of what has already been discussed (Table 1):

MODEL	Chan&Qi	SCOR	Gunasekaran	Chae	ANP
APPROACH					
Process	X	X			
Hierarchial			X	X	
SC paradigms					X
LAYERS	3	3	3	2	4
PERFORMANCE PARAMETERS					
Cost	X	X	X		X
Time	X	X	X	X	X
Capability	X	X	X	X	
Productivity	X		X	X	
Utilization	X		X		
Reliability	X	X	X	X	x
Availability	X			X	
Flexibility	X	X	X		X
Assets		X		X	
Outcome	X	X	X	X	X
EMPHASIS	Cross-functionality	Strategic decision-making	Level of decision-making	Practical implementation	Growth and survival
ADVANTAGES	Deep insight of the process performance, more visual information about the management effectiveness, monitoring and resource allocation, process re-design and benchmarking	Improved alignment and enhanced communication, rapid assessment and clear identification of gaps, desing and set-up of a measurement system for efficient supply chain	Good assessment of supply chain performance at each level of decision-making and fair decisions	Easy and fast implementation	Make strategic decisions that are essential for growth and survival of supply chains
DISADVANTAGES	Too functional, does not pay enough attention to the overall company strategy and missions, tricky to aggregate results	Need for further improvement	Not applicable to all supply chains in all industries	Too simple and limited scope	Not generalized to other product categories or services, cumbersome and difficult to apply

Table 1: *Comparison of Measurement Frameworks (own construction)*

2.5 Theoretical framework

After reviewing the most common frameworks we advocate the combination of process- and hierarchy-based approach for its balanced view. It enables process control and re-design, and therefore enhances efficient resource allocation and provides the opportunity to evaluate the effectiveness of the supply chain. Process-based approach is a natural way of modeling measurement framework, since it follows normal supply chain phases (plan-source-make-deliver-return). Process-based model also dilutes the structural barriers and encourages cross-organizational integration (Chan & Qi, 2003a). Of crucial importance is to measure the outcomes of those processes and subprocesses that are essential to achieve the supply chain objectives and strategic goals. In addition, the hierarchy-based approach will enable the managers at various levels to follow supply chain performance in detail. Dimensions of metrics should include at least the most common parameters; cost, time, flexibility and outcome. We argue to have only two layers of metrics, primary and secondary ones, since according to Gunasekaran & Kobu (2007), a measurement framework should be simple and practical. Primary metrics represent a company's E2E supply chain performance, whereas secondary metrics give a more detailed view of the supply chain and illustrate specifically why a primary metric is performing high or low (Chae, 2009). Chae (2009) emphasizes to start with a few metrics that are the most critical for the supply chain. That is our aim as well.

Having assessed the various models we base our framework on the SCOR model. This model is chosen due to its process-based, balanced approach and comprehensive inclusion of distinct performance dimensions. It links business processes, performance attributes and metrics into one framework, and has a hierarchical reach enabling drilling down into lower measurement levels. It is also one of the most widely cited and globally applied models, which is used as a basis for many other frameworks. This is an indication of the model's suitability for various contexts.

We adapt the five performance attributes of the SCOR model; reliability, responsiveness, agility, costs and assets. A performance attribute is a group of metrics used to express a strategy, but an attribute itself cannot be measured (SCC, 2010). In addition, we have applied some of the proposed top level (primary) metrics for these attributes. These are aimed at helping management in evaluating the effectiveness and efficiency of the E2E Product X supply chain. In order to get a deeper understanding of the facts affecting these main metrics it is essential to look at the processes. The four main processes plan-source-make-deliver are analyzed and metrics for these assigned accordingly. Each supply chain process, subprocess and activity is supposed to contribute to the E2E supply chain. As a simplification, we have excluded returns and focus solely on forward flows.

As stated earlier, the SCOR model emphasizes a strategical approach, but is not very sensitive to market changes. It is also rather complex with three layers of metrics and processes. Therefore, besides applying primary and secondary metrics as suggested in the framework of Chae (2009), we also propose to use more tactical and operational metrics in particular as secondary metrics, referring to the model of Gunasekaran et al (2004). Further, we have applied features from the other two models as well by using a multidimensional set of metrics, balancing hard and soft metrics as recommended by Chan & Qi (2003a). We have also taken into consideration turbulent market environment and applied metrics for flexibility, adaptability and responsiveness, as suggested by Agarwal et al (2006).

The theoretical framework and metrics are presented in Table 2, which also includes a list of the most common activities related to each main process, as proposed by the SCOR model (2010). Further the explanation of each performance attribute, as well as primary and secondary metrics follow suit.

COST	AGILITY	RELIABILITY	RESPONSIVENESS	ASSETS	Processes
E2E SC Costs	Ttl Response Time to Changed Conditions	Perfect Order Fullfilment	Ttl Order Fullfilment Cycle Time	Cash-to-cash Cycle Time, Return on Fixed Assets	
PLAN	*PLAN*	*PLAN*	*PLAN*	*PLAN*	Gathering customer requirements, collecting information on available resources, balancing requirements and resources to determine planed capabilities and resource gaps
Information processing costs	Time to market	Forecast vs order	Planning cycle time	Ttl inventory days of supply	
Inventory carrying costs		Forecast vs sales	Order lead time	Obsolete inventory	
		Forecast volatility			
		Order availability			
		Stock-out rate			
SOURCE	SOURCE	SOURCE	SOURCE	SOURCE	Issuing purchase orders, scheduling deliveries, receiving, shipment validation and storage, accepting supplier invoices
Sourcing costs	Time to adjust product volumes and mix	Supplier fill rate (right quantity, product, documentation, date, condition)	PO cycle time	Economic order quantity	
IB transportation costs	Time to adjust supplying frequency	On-time arrival from factory to DC	IB transportation lead time	IB Transportation space utilization	
		On-time departure from factory to DC		Overdue invoices (accounts payable)	
MAKE	*MAKE*	*MAKE*	*MAKE*	*MAKE*	Assembly, chemical processing, maintenance, repair, overhaul, recycling, refurbishment, remanufacturing etc
Manufacturing costs	Manufacturing change-over time	On-time production	Manufacturing lead time	Capacity utilization	
	Time to adjust manufacturing product volumes and mix	Quality tracking (free from errors)			
	Time to adjust manufacturing frequency				
DELIVER	*DELIVER*	*DELIVER*	*DELIVER*	*DELIVER*	Receipt, validation and creation of customer orders, scheduling orders delivery, pick, pack and shipment, invoicing the customer
OB transportation costs	Time to adjust deliveries according to special customer needs	On-time arrival from DC to end-customer	OB transportation lead time	Accounts receivable	
Warehousing costs		On-time departure from DC to end-customer	Complaints resolution time	Warehousing facility utilization	
		Faultless delivery notes/invoices		OB Transportation space utilization	

Table 2: *Theoretical Measurement Framework (own construction)*

2.5.1 Costs

Costs are measuring total supply chain expenses incurred from management, labor, materials, transportation and other activities. E2E supply chain costs include direct and indirect costs of processes and activities related to different phases of the supply chain, as well as direct labor and material costs allocated to different products. (SCC, 2010)

Of special interest in the planning phase are information processing costs (Gunasekaran et al, 2004) and inventory carrying costs (Chan & Qi, 2003a), since they are among the largest expenses contributing to the E2E supply chain costs. If the supply chain is to become more integrated it is essential to invest in advanced Information Technology (IT) systems to enable transparent exchange of information, which accumulates to high information processing costs (Gunasekaran et al, 2004). Inventory carrying costs refer to the cost of keeping and storing inventory. In relation to sourcing, supplying costs and costs of inbound transportation (from suppliers to warehouses/distribution centers) should be taken into consideration, as major costs. (SCC, 2010) A useful metric for measuring production is manufacturing costs, whereas outbound transportation and warehousing are the biggest items influencing delivering costs and are therefore suggested to be measured as well. The lower all these costs, the more cost-efficient the total performance of the supply chain. (Chan & Qi, 2003a)

2.5.2 Agility

Agility measures the capability to respond to key supply chain changes. That is, it assesses how well the company is able to react to internal and external changes having the same level of cost, quality and customer service. Agility is measured through adaptability and flexibility, and includes a time-element by measuring total response time to changed conditions (SCC, 2010). Adaptability has a longer perspective, looking at more profound changes, such as new distribution channels or new distribution destinations, whereas flexibility estimates short-term adjustments, such as an ability to act on a machine breakdown or express orders/deliveries. (Agarwal et al, 2006)

The theoretical framework recommends total response time to changed conditions as a top level/ primary metric. At the planning phase it is proposed to evaluate new product development and introduction time by measuring time to market (Agarwal et al, 2006). This is defined as the total time, which is required from catching the product idea until launching the new product into the market. As product lifecycles continue to decrease, compressing development cycles and accelerating new product introductions are becoming critical. The shorter the time to market, the better the company can adapt to changes (Agarwal et al, 2006). Flexibility at sourcing is concerned with adjustments in product mix/volumes and supplying frequency (Chan & Qi, 2003a; Chan & Qi, 2003b); whereas at making it is dealing with manufacturing change-over time, time to adjust manufacturing product mix, volumes and frequency (Gunasekaran et al, 2004). Agility in delivering should be measured as well, by following time to adjust deliveries according to special customer requirements (Agarwal et al, 2006). Again, the shorter these times the better the company adjusts to internal and external changes.

2.5.3 Reliability

Reliability is measured by analyzing if deliveries are done at the right time, delivering right quantity, and right product, to the right place, free of faults, in perfect condition and with accurate documentation. The proposed top line metric is perfect order fulfillment, which takes into consideration all of the above mentioned aspects. The higher the order fulfillment, the better the customer service level and thus the greater the customer satisfaction. (SCC, 2010)

Supply chain planning relies on forecasting data; therefore forecast accuracy is of uttermost importance. The theoretical framework suggests measuring forecast versus order and forecasting versus sales. This means that the amount forecasted is compared to the actual amount of ordered and sold. It might be the case that forecast versus order is high but forecast versus sales low, which indicates that the problem is not within forecasting but rather in processes (Chae, 2009). Further, it is recommended to measure forecast volatility, since high volatility causes the well-known bullwhip effect upstream in the supply chain making production and supply planning very challenging (Chae, 2009). Volatility monitors the variation of forecasts for a specific period.

Other important metrics are order availability and stockout rate that measure inventory availability (Chae, 2009). Order availability refers to orders that can be immediately fulfilled from stock. Stockout rate monitors the frequency of stockout per order cycle (Chan & Qi, 2003a). Supplier fill rate is another metric proposed by the theoretical framework, evaluating sourcing performance where focus should be in supplier delivery accuracy (right quantity, product, documentation, date and condition) (Chae, 2009). Also, inbound transportation is measured by monitoring on-time arrival at the distribution center (DC) and on-time departure from factory. In relation to making on-time production and quality tracking (free from errors) are presented as secondary metrics and for outbound delivery on-time departure from DC and on-time arrival at end customer. (Chae, 2009) It is also recommended to follow the number of faultless delivery notes/invoices (Gunasekaran et al, 2001).

2.5.4 Responsiveness

Responsiveness represents time and measures different cycle times. It evaluates how quickly supply chain can satisfy customer demand. The suggested top level metric is total order fulfillment cycle time, which is an aggregated metric of all time-related secondary metrics. (SCC, 2010)

Planning cycle time is one of the secondary metrics proposed as well as order lead time (Agarwal et al, 2006). The length of the planning cycle time is a good indicator of the level of responsiveness, where short planning cycle time is desirable. Planning cycle time is connected to sales and operations planning (S&OP), and aims at balancing demand and supply (Chae, 2009). Production and material purchasing is planned according to forecast data about demand (Chae, 2009). For each individual order the order lead time starts from the order receipt and ends with customer acceptance of the order. The shorter the planning cycle time and the order lead time the more responsive the supply chain is towards customers. At the sourcing phase the theoretical framework suggests to use purchase order cycle time and inbound (IB) transportation lead time (Chae, 2009). Purchase order cycle time is the time it takes from preparing a purchase order to submitting it to a supplier. Concerning making the manufacturing lead time adds to metrics of responsiveness, while delivering phase should measure outbound (OB) transportation lead time. It is also important to assess how fast customer complaints are handled. Hence, this is another secondary metric evaluating responsiveness (Gunasekaran et al, 2004). The shorter all of these cycle/lead times, the less uncertainty concerning customer demand and the better service level towards end-customers (Gunasekaran et al, 2004).

2.5.5 Assets

Assets evaluate how efficiently the supply chain uses the assets and resources. The top level metrics are cash-to-cash cycle time and return on fixed assets, which measure respectively the time a company takes to recover its financial investment from purchasing and how profitable a company is relatively to its total assets. The shorter the cash-to-cash cycle time and the better the return on fixed assets, the less financial resources are tied-up and the more efficiently the company is using the assets. (SCC, 2010)

At the planning phase it is proposed to measure total inventory days of supply and obsolete inventory, since these are significant items contributing to tied-up capital (TUC) (Chae, 2009). Inventory days of supply evaluates how long a company's average supply of inventory will last, while obsolete inventory is a metric measuring the stock that has not been sold at the end of its useful life. The less days of inventory, the lower the investment in inventory and hence the lower the risk of inventory write-off (Chan & Qi, 2003a). At sourcing, economic order quantity and transportation space utilization (IB) can be used to optimize the level of tied-up capital. Economic order quantity minimizes the costs involved in ordering by finding the optimal size for order amount and the optimal order frequency (Gunasekaran et al, 2004). For the making phase following capacity utilization is recommended, which measures how efficiently the resources are being used in manufacturing. For delivering, warehousing facility and transportation (OB) space utilization should be evaluated (Chan & Qi, 2003b). Furthermore, the effectiveness in invoicing the deliveries (accounts receivable) should be evaluated, as well as the settlement of payments of the sourcing (accounts payable) (Gunasekaran et al, 2004).

3. Methodology

3.1 Research design

Analyzing supply chain performance is mostly done in quantitative context, resulting in financial metrics. Numerical measures do however not always reveal performance objectively and may remain vague (Beamon, 1999). Therefore, the research methodology of this paper unfolds under the interpretivist paradigm and qualitative methods are employed in order to explain the phenomenon deeper. According to Collis & Hussey (2009), a case study is used to explore a phenomenon and obtain in-depth knowledge within a particular context using various methods. The case study technique is the most suitable for this research, since the aim is to understand the relations of various parameters in a particular context, the Product X supply chain, and define the supply chain measurement framework and metrics accordingly. This is an explanatory/opportunist case study, as having access to Company X information enabled examination of the Product X supply chain in-depth, using existing theory to understand the context and hence deliver the research goal.

There are many existing performance measurement theories; however this study is not restricted by them. The objective is to make use of these theories by combining their best parts (those most suitable and applicable for Product X and develop a specific model for Company X. This will enable the company to find the root causes to problems, and thus enhance efficiency and effectiveness of Product X supply chain. Since this is a case study at only one company the sample size is small, which is characteristic for an interpretivist research. The study follows the deductive logic, because it moves from the general part, where the theoretical measurement framework is presented, to becoming more specific, by forming a measurement framework just for Product X. Moreover, this is an applied research, as the paper's outcome gives solutions to specific and existing problems for Product X supply chain and is mainly contextual.

3.2 Research strategy

The research includes theoretical, empirical and analysis parts. The theoretical section consists of literature review and the development of theoretical framework. Literature review, which is mostly based on revision of articles from academic journals, enables gaining insight and knowledge of the explicit concepts of supply chain measurement and the common metrics used. “Supply chain measurement”, “Supply chain metrics”, “Performance measurement”, “Measurement framework” are examples of used keywords when searching the relevant literature. The most ordinary frameworks are introduced, which were chosen according to the number of citations; these are among the most discussed ones in the academic literature. The main idea of the models is described without going deep into details.

A comparison of different measurement models and a presentation of the theoretical measurement framework conclude the theoretical part. A matrix is created to illustrate more systematically advantages, drawbacks and the main differences between the various approaches in a visual format. The theoretical model incorporates the most essential and relevant parts of all the previously presented frameworks and is tailored after a set of presented design criteria in order to ensure its utmost suitability. The framework is designed in such a way that it is proactive instead of reactive. That means that any issue should be able to be identified and confronted as early as possible, before it becomes a real problem. In case a problem reaches the end-customer the company should be able to react quickly; to be responsive.

The empirical part is carried out as a case study of the Product X supply chain at Company X and involves interviews as the main method of data collection. The aim is to interview different stakeholders in order to understand the business, the current measurement system and the challenges Company X is facing concerning the Product X supply chain. Further, the chosen market flows, processes and existing KPIs of the Product X supply chain are reviewed and mapped. There is a need to understand the relations of different variables and how they affect the overall performance of the Product X supply chain. It is also important to understand the value proposition throughout the whole supply chain, as well as the main strategic targets of the Product X supply chain. The relevant data collected is fit into categories using the pre-existing theoretical framework and summarized in the form of diagrams to make analysis easier.

In the analyzing part the purpose is to find the main gaps of the existing measurement system compared to the proposed one, and thus develop a specific framework for the Product X supply chain and suggest relevant metrics. Investigation of the current measurement system and metrics enables the identification of possible deficiencies in the measurement practices and delivers valuable information for determining new metrics, making improvements and adaptations to the existing ones or even removing some KPIs. The aim is to develop a specific measurement framework with relevant metrics to help the managers of Company X in measuring the performance of the Product X supply chain. The interest of the management is to get fact-based information of the Product X supply chain performance in order to be able to identify where any problem originates from and thus make the right decisions concerning the allocation of resources. This will enhance the stabilization of the Product X supply chain and hence strengthen the organizational competitiveness by improving customer service level at an affordable cost. Moreover, in this part a number of challenges that the company is facing regarding E2E Product X supply chain performance measurement are listed. This is a result of analyzing the empirical data collected and interacting with the different stakeholders/interviewees.

3.3 Methods of data collection

In this research the main method for data collection are interviews. They take place more or less at the same time with the development of the theoretical framework. According to Collis & Hussey (2009), qualitative data needs to be understood within the context, therefore there is a need to define the frame first. Contextualization of data is done by first exploring the literature, and then collecting and introducing the background information of the Company X and the Product X supply chain. In order to perceive the context right an introductory meeting took place with Company X's global supply chain planning team headed by the global supply chain planning manager. The objective was to learn about the company, in particular about the Product X supply chain, and define the problem statement. At that meeting it was agreed to have review meetings with this reference group every second week to follow the progress of the research and discuss relevant matters and concerns.

Between the review meetings several teleconferences and a few face-to-face interviews were held with key stakeholders from the company, mainly managers in focus areas of this research. In some cases the interview was conducted via email. The most common methods used were unstructured and semi-structured interviews. There were 25 interviews in total. Many interviews were more like conversations that evolved during the course of the interview. Before each interview some of the questions were prepared in advance, which served as a guide for the interview (Appendix 5). Questions and matters explored did not change much for each interview, but were always adapted and directed according to the interviewees' area of responsibility. Hence, different aspects of the topic were investigated and revealed each time. Prompts and probes were used in order to get the interviewee to elaborate on his/her initial statements and thus ensure that maximum information was gained out of the interview. Most of the questions were open-ended and summary questions were normally used before the interview came to an end. Predominantly two-to-one interviews were conducted, us two interviewing one person at a time (individuals), but also a few two-to-two interviews (in groups). Sometimes the interview would take place at the company's premises where one of the interviewees would be present, while the other one would join the meeting via telephone. The reason why there were more teleconferences than face-to-face interviews was the inability to meet with the interviewees, as they are located in different countries (Collis & Hussey, 2009).

The held interviews are categorized as primary data. In addition to this, secondary data was used in the form of various internal company reports and other documents that were submitted by Company X. The documents contain mainly quantitative data and are follow-up reports Company X uses in everyday operations.

3.4 Validity and reliability

The aim of this paper is to get deep into the research study and accurately reflect the case. The opportunist case study design itself enabled gaining full access to stipulating high quality, original data; however that was limited to the Product X supply chain aspects. The interviewees were top executives in their field of expertise, which illustrates that the data was collected from people with high knowledge and awareness of the situation and the problems surrounding it. Therefore, there are no indications of a lot of potential error and bias in the information gathered. All the participants were aware of the purpose of this research and participated voluntarily. Hence, there is not seen to be any major ethical issues involved either. The stakeholders were very open throughout the process, showing no signs of resisting any topic and talked confidently about the issues the way they see, think and feel them.

Generally, it is characteristic of a qualitative study to be of high validity. On the other hand, it is typical that the researchers interact with the phenomenon being investigated and that their interpretations are partly subjective (Collis & Hussey, 2009). It is felt that this study has established and understood the contextual framework to a high level, and thus valid qualitative data was collected and correctly interpreted. Nonetheless, in order to reduce subjectivity and improve validity of the paper, summaries of the findings were sent to the interviewees for feedback on the interpretations. Moreover, the progress of the research and the data collected were presented at each review meeting with the global supply chain planning team and then immediate feedback was gained. Hence, it is assumed that the internal validity of this paper is high. However, there is no external validity. The proposed measurement framework is contextual and depends on specific, interrelated variables, hence is not as such to be generalized to other supply chains within Company X or to other companies. The theoretical measurement framework, on the other hand, can possibly be generalizable as it stands.

The reliability in this case study depends on how a researcher perceives the current Product X supply chain and which approach is applied to develop the framework. Low reliability is characteristic for the interpretive paradigm, since it is difficult to get the same results in a qualitative study after replication (Collis & Hussey, 2009). Since most of the interviews were not held face-to-face, it was not possible to observe gestures or body language. Even though this would have been the most suitable in order to gain a better understanding of the respondent's world, especially when the context and problem statement is complex and not very clear. This may have affected the reliability of this paper. At each interview the same questions were asked, using the same basis, with the only difference being that the questions were addressed based on their field of expertise. It is firmly believed that this enabled drawing reliable conclusions and extracting reliable results. However, subjectivity may have influenced the reliability of this report, which is an important fact to take into consideration.

4. Empirical findings

Product X antiseptics are categorized into two product brands. The main markets for Product X include several European countries, in specific; UK, France, Benelux, Ireland, Italy, Spain, Germany, Austria, Switzerland, Greece and the Nordics. The product itself is the same for all countries, the only things that change are labels and in some cases specific leaflets and cartons. These vary due to language differences or differences in requirement specifications imposed by each country's health care authorities (Internal company report on antiseptics, 2014).

Overall, the healthcare market is strictly regulated and constantly under the review of various authorities. The European market, in particular, is controlled by the EU Medical Authority and the Ministry of Health (MOH) in each country. There are regulatory rules, strict guidelines and restrictions that must be followed. For example, in order to release the Product X products into the market a certificate of analysis is needed for each batch, which is issued by the Qualified Person (QP); the QP specializes in assessing batches. All this makes business practices even more challenging as there are a lot of certificates, licenses and permits needed to operate and sell the Product X products in each market. Pharmaceuticals are the most regulated group and are constantly under the surveillance of the previously mentioned authorities. Shortly new and stricter regulations will be imposed, as pharmaceuticals will have to be transported in temperature controlled vehicles and stored under special conditions. This will strongly affect transportation and storing of Product X products. Biocides are more flexible than pharmaceuticals, as they have fewer constraints. Still, there are mandatory rules and regulations that must be followed for this product category as well (Interviewees 2&12).

4.1 Product X supply chain

Company X purchases finished Product X products from contract manufacturers. The most important contract manufacturer for the European market is Company Y, located in Country A. Company Y has been producing health and beauty products since 1933 and is one of the largest health and beauty contract manufacturers in Western Europe (Company Y, 2014). The company supplies for more than 60% of the Product X products Company X purchases (Internal company report on contract manufacturing, 2014). Company Y is in turn supplied by other companies, for instance German-based Company Q that supplies chlorhexidine digluconate (CHG) and by various packaging material providers.

The finished goods are transported from Company Y by third-party logistics providers (3PL) to warehouses or straight to distribution centers (DCs) and from there further to end-customers. Logistics service provider X is a dedicated partner that takes care of most of the inbound and outbound transportation of Product X products on behalf of Company X. This is done by trucks. Logistics service provider X is a global supplier of transport and logistics solutions, and Logistics service provider X Road is ranked third in the leading logistics providers list in Europe (Logistics service provider X , 2014). The rest of transportation is taken care of Logistics service provider Z that is another transport and logistics solutions provider (Interviewee 9).

4.1.1 Country A flow

The Country A flow (Picture 7) is a make-to-stock flow. It starts with the Country A sales organization entering the forecast for all Company X products sold in Country A. This is done by running the Advanced Planner and Optimizer (APO) module on SAP. APO enables them *"to forecast and plan the demand in consideration of historical demand data, causal factors, marketing events, market intelligence, and sales objectives"* (SAP, 2014). On the other end, the Country A Customer Service Center (CSC) is responsible for entering the sales orders into the system, some of which are entered automatically via Electronic Data Interchange (EDI) orders, giving at the same time availability dates to customers (Interviewee 1).

Product availability is regularly checked by Company X using another SAP module called Availability Check (ATP) Function. Material Requirements Planning (MRP) identifies if more products are needed to satisfy a sales order depending on the amount of inventory at SEWA SL01 and SL05, and SAP proposes a requisition accordingly (PuReq). SEWA SL01 is a 3PL warehouse (run by Logistics service provider Y) located in Country C, where antiseptics are stored among other products; Company X has the ownership of the stock. Due to limited storage capacity of pharmaceutical products at SEWA SL01 Company X keeps also stock at SEWA SL05, a buffer warehouse (run by Logistics service provider X), which is located in Country C. Company X owns that stock as well. SEWA SL05 is a temporary solution for pharmaceutical antiseptics, which is not integrated with SEWA SL01. Pharmaceuticals are shipped directly from Company Y to SEWA SL05 if SEWA SL01 pharma zone is full. There they are first stored and then used to replenish the stock at the central SEWA SL01 warehouse (Interviewees 1& 2).

If more products are needed to satisfy a sales order the CSC contacts a team called the Customer Service Information Officer (CSIO), which is doing the link between all CSC departments and the Supply Chain Planners (SCP). Requisitions are then manually turned into purchase orders (POs) once a month via a defined ordering process with Company Y. SCP is responsible for placing the POs via SEWA SL01 to Company Y. The POs are sent by e-mail to Company Y and a discussion is initiated. Company Y informs SCP about availability and both parties agree on quantities and delivery dates. Company Y produces the required Product X products and informs SCP when products are ready to be dispatched. The SCP plans transportation quantities and capacity, and in turn informs the logistics team in Country C), which organizes pick-up and transportation at Company Y by Logistics service provider X. Products are shipped from Company Y to SEWA SL01 or SEWA SL05 as explained previously, but are delivered to end-customers only from SEWA SL01 (Interviewee 1&8). Company Y invoices SEWA SL01 and Company X logistics team in turn notifies SEWA SL01 with a good receipt (GR) and good issue (GI). Further, CSC invoices the end-customers according to the sales order. Invoicing procedures are most of the time performed automatically via SAP (Interviewee 7).

The end-customers in the Country A market consist of hospitals that order directly from Company X, private sector hospitals that order either directly from Company X or via a trusted partner and large distributors/wholesalers, who place bulk orders and may supply hospitals, pharmacies or other smaller distributors (Interviewee 4).

4.1.2 Country B flow

For the Country B market (Picture 8) forecasting, planning and ordering works more or less the same way as in the Country A market. Additionally, a duplicate of the PO is issued on a fictive plant (SEKE) for the administrative functions. SCP plans transportation, informs the Company X logistics team in Country C that organizes pick-up and transportation similarly to the Country A market. The products are delivered by Logistics service provider Z directly from Company Y to the local distributor, Company Z. Company Z is a sub-contractor that sells Product X products in the Country B market on Company X's behalf. Company Y Company Y invoices SEKE, which in turn invoices Company Z. Then, SEKE is also notified with a GR from the logistics team in Country C. CSC in Country C updates manually the stock information on SAP daily according to Company Z's weekly sales and it is checked that there are no discrepancies between SAP stock and physical stock at Company Z. Sales orders are dealt directly by Company Z and customers (Country B hospitals) place their orders to Company X only via Company Z (Interviewees 2&5).

More detailed explanation of processes and subprocesses of the two flows are presented in Appendix 3.

4.2 Strategy for Product X

Company X is facing a triple trade-off for Product X supply chain. That is, if they should focus on low cost, high customer service or low inventory. For example, providing a high customer service level may come at a higher cost for Company X as they might need to keep a higher inventory level. The current strategy for Product X at the supply chain level is to stabilize its performance and improve customer service level. That entails increasing credibility towards customers at affordable cost. Management stresses that in order to succeed in this type of market and maintain a sustainable supply chain it is necessary to improve the Product X supply chain performance. At this point the focus at strategic level is on how supply chain planning (SCP) can tackle the repetitive problems that appear in the E2E Product X supply chain. Moreover, at tactical level the goal is to increase capacity and become more agile, whereas at operational level the aim is to increase reliability (Interviewee 10).

4.3 Company X measurement system

Company X uses the balanced scorecard (BSC) to measure and evaluate supply chain performance. The BSC consists of primary and secondary KPIs, out of which some measure performance only at aggregated/company level, division level or per flow, not by supply chain. Supply chain management uses service, financial and internal KPIs to measure performance of all supply chains. Service related KPIs measure value proposition towards the customer and include order line completeness (OLC), backorders (BO), freight to customer (FTC) and service complaints. Financial KPIs measure financial outcome and consist of total supply chain costs, supply chain costs as percentage of sales, obsolete/scrapping costs and inventory costs. Internal KPIs measure performance of internal processes by evaluating transportation lead time, the percentage of credit/debit notes versus orders and forecast accuracy (Interviewee 10).

Company X also uses a system of supplier performance measurement (SPM) to evaluate the effectiveness of the procurement and especially the raw material supply processes. Supplier performance is evaluated by comparing the actual handover date to the acknowledgment date (plus in advance agreed tolerance period). Depending on the result of SPM analysis possible corrective actions are taken to improve the situation (Internal company report on SPM, 2014). However, SPM is not currently used for analyzing Company Y since the program is not set for analyzing contract manufacturing. Hence, it is internally felt that SPM is not suitable for measuring performance of Company Y (Interviewee 3).

4.3.1 Order line completeness

OLC is measured weekly on supply chain level by comparing the number of missed lines to the number of lines ordered (planned). An order line is regarded as missed if the actual Goods Issue (GI) date of an item does not match the requested GI date. The GI date is defined as the transaction date (Oracle, 2014). Order lines can be missed when stock is not available, but even when stock is available. For instance, if the customer wants the products on a Monday but the delivery is on Tuesday will this be considered as a missed line. OLC is based on daily SAP data and is a one shot miss; if an order is re-scheduled the order is not followed further for hit or miss. The OLC targets are very high and have always been very challenging to reach (Internal company report on OL KPI definitions, 2013).

4.3.2 Backorders

BO is measured on supply chain level by comparing the actual BO in value (euro) and the number of lines to the target BO value and the number of lines. In addition to that a BO report is created, which includes all ordered lines that have not been delivered or served for whatever reason (Internal company report on OL KPI definitions, 2013). There is an attempt to find out the cause of backorders, whether it is due to production problems, quality issues, unclear processes, transit issues or something else. At the same time the availability is being checked as well as planned timing for the delivery of backorders. The BO report is based on weekly SAP data (Internal company report on BO, 2014).

4.3.3 Freight to customers

Freight to customers (FTC) is measuring performance of the final delivery; from warehouses or DCs to final customers (Interviewee 8). FTC is followed at aggregated level globally, regionally and by market, hence performance at product supply chain level is not currently being measured. Actual delivery times are compared to the planned ones and reasons for delays are reported (Internal company report on FTC, 2014).

4.3.4 Service complaints

Service complaints are counted as percentage of orders. They include any kind of complaint concerning external or internal services; ordering, transporting, warehousing, delivering, invoicing etc. Service complaints are followed at supply chain level (Interviewee 10).

4.3.5 Total supply chain costs

Total SC costs measure planning and execution costs in euro across the whole supply chain at aggregated level. It is the metric for the total management costs from planning until return including home-taking costs (i.e. transportation costs from factories to DCs/warehouses), warehousing costs (i.e. warehousing costs at DCs/warehouses and central supply chain management costs), and freight to customer costs (i.e. distribution costs from DCs/warehouses to customers) (Interviewee 10).

4.3.6 Supply chain costs as percentage of sales

Supply chain costs as percentage of sales compares the total SC costs to actual sales and includes items such as labor and material costs. This is also measured at aggregated level (Interviewee 10).

4.3.7 Obsolete/scrapping costs

Obsolete/scrapping costs include the value of lost sales due to obsolete inventory and cost of scrapping products (i.e. return of pharmaceuticals). This is measured in euro at divisional level i.e. for wound care and surgical division (Interviewee 10).

4.3.8 Inventory

Inventory measures operational and financial inventory. Operational inventory is assessed in terms of value at budget rate (euro), days of sales and forward cover, whereas financial inventory is estimated in terms of value at current exchange (euro) and days of sales. Financial inventory in value at current exchange consists of operational inventory plus a finance bridge at aggregated level (i.e. total wound or surgical) which is the official yearly budget to achieve, in other words not to exceed. Operational inventory in value at budget rate measures raw materials at factory, semi-finished goods at factory, finished goods at factory, in-transit stock from factories to DCs and local warehouses and finished goods at DCs and local warehouses. Operational inventory in days of sales measures stock in hand versus past sales. Operational inventory in forward cover follows stock in hand versus sales forecast. Operational inventory is monitored at supply chain level, whereas financial inventory is evaluated at aggregated level (Interviewees 1&2).

4.3.9 Transportation lead time

Transportation lead time adherence is measured between factories and warehouses or DCs. This is done by flows, not by supply chains (Interviewee 10).

4.3.10 Credit/debit notes versus orders

The number of credit and debit notes is compared to the number of orders and this is measured as a percentage of orders. This metric is followed at supply chain level (Interviewee 10).

4.3.11 Forecast accuracy

Forecast accuracy compares actual sales to forecasts and is measured by two KPIs; BIAS and PLIX. BIAS is a measure of error that estimates how accurate the total forecast is compared to the actual sales. BIAS addresses the total volume and does not pay attention to which products (SKUs) are forecasted. BIAS gives indication if the market is over/under forecasting. PLIX (planning index) evaluates the accuracy of the product mix. Forecasting is done by products and therefore at supply chain level (Interviewees 1&2).

4.4 Product X procurement scorecard KPIs

For contract manufacturing (CM), as the case of Product X, Company X uses a procurement scorecard. The procurement scorecard KPIs are order line completeness, complaints per million and tied-up capital, which measure quality, supply and financial performance accordingly. The current measurement system is internal and not integrated with suppliers and customers across the supply chain (Interviewee 1).

4.4.1 Order line completeness

Measuring OLC was already discussed under the general measurement system. OLC is followed weekly, analyzing reliability of the Product X supply chain.

4.4.2 Complaints per million

Complaints per million (CPM) measures the number of all incoming complaints from end-customers of Product X products per million of pieces sold. CPM is a measure of reliability and service quality, which is monitored monthly via SAP data.

4.4.3 Tied-up capital

Tied-up capital (TUC) measures the operational inventory value in euro and days of sales at Product X supply chain level. It is compared with OLC or BIAS (forecast accuracy) in order to measure the inventory balance (Interviewee 2). A certain level of safety stock is needed at warehouses so that the inventory level does not fall under an unwanted level. The proper level of safety stock depends on the products and warehouses, and is checked on a weekly basis. However, the safety stock itself is not being monitored. TUC is followed weekly using SAP data and is assessing financial efficiency of the operational assets (Internal company report on Inventory Management Model, 2014).

4.5 Product X process-based KPIs

4.5.1 Planning KPIs

To measure the performance of planning the Product X supply chain, Company X is currently using three secondary KPIs. They include order line availability, backorders and forecast accuracy. All evaluate reliability contributing to OLC.

4.5.1.1 Order line availability

OLA is measuring reliability of planning the sourcing. It is divided into: OLA Warehouse and OLA Factory. OLA Factory is theoretical KPI, which is used by Company Y to track the number of backorder lines not related to a supply issue from the factory. This is to say the reason for backorders does not depend on the factory, but on something else in the process. OLA Factory functions as a basis for SLAs towards the supplier (Company Y) measuring the service level. OLA Factory is followed weekly (Interviewee 2).

OLA Warehouse tracks the number of order lines not delivered to end customers due to stock-outs on planned GI dates. The figure therefore estimates the accuracy of supply chain planning (SCP) on Material Resource Planning (MRP) level based on daily SAP data, which is afterwards consolidated into a weekly number. Again, it measures the amount of BOs not related to warehouses but to something else in the process (Interviewee 11).

OLA tends to be higher than OLC; they normally gap by approximately 5% (Interviewee 3). If OLA is 97% and OLC is 92%, then there are 5% of missed order lines due to something else but supply or warehouse related reasons (mainly other process issues) and 3% of missed order lines due to supply and warehouse issues (Internal Company report on OLA, 2014).

4.5.1.2 Backorders

Backorder value of orders and number of lines was explained under the general Company X measurement system. Backorders is measuring reliability of inventory requirement planning (Interviewee 2).

4.5.1.3 Forecast accuracy

Forecast accuracy reports compare the demand received (sales) per month with the forecast for that month as already described, analyzing the reliability of demand forecasting. Local markets are in charge of delivering forecasts for particular market areas (Interviewee 6). Both BIAS and PLIX are followed in two versions: one month version and rolling 3 month average version. Forecasting is mostly based on historical data (Internal company report on antiseptics forecast accuracy, 2014).

4.5.2 Sourcing KPIs

Company X has introduced five secondary KPIs towards Company Y; supplier capability, product manufacturing complaints, overdue invoices, plan attainment and overall equipment efficiency. These KPIs are all measured monthly. Sourcing costs including supplier pricing deviation are also followed at Product X supply chain level.

Further, Company X measures performance of inbound transportation using three secondary KPIs; on-time arrival from factory to DC, non-conformity notifications and damaged goods upon arrival at DC. This concerns only the Country A market, since the flow to the Country B market is evaluated by Company Z and IB transportation is not measured at all by Company X.

4.5.2.1 Supplier capability

Supplier capability is assessed by OTIF, which measures the capability of the supplier to deliver "on time and in full". OTIF is measured manually by Company Y, using the base data from the Company X purchase orders and applying the service level agreement to score it (Interviewee 3). It is followed monthly, analyzing reliability of the supplier (supplier evaluation). It evaluates if the supplier is capable of delivering what has been requested in terms of accuracy in quantity and on time (in days). OTIF is not centrally given; instead it is "pushed" into the supplier (Company Y) and rolled with all the supplier processes (Internal company report on OTIF Company Y, 2014).

4.5.2.2 Product manufacturing complaints

Product manufacturing complaints measure the number of complaints received that are related to product manufacturing issues. Product complaints (4.5.3.3) are generated externally from customers, received at Company X and then passed on to Company Y. The product complaints are registered by the Company X local markets into SAP and then the Company X quality team passes them to Company Y in the form of corrective action and preventive action (CAPA). All product complaints coming to Company X are at first assumed to be connected to manufacturing. Company Y reviews the product complaints and is challenged to respond if the complaint actually is connected to a manufacturing default. Confirmed complaints are registered as product manufacturing complaints. Company Y also needs to estimate how long it takes to solve the problem. For product manufacturing complaints the emphasis is on closing them down; the aim is to have zero open complaints. This KPI measures reliability of quality assurance (Interviewees 3&4).

4.5.2.3 Plan attainment

Plan attainment is an internal KPI at Company Y, which measures actual production output versus planned. The data that is used to measure this KPI is generated from Company Y's own internal manufacturing system. Plan attainment helps Company X to monitor how well Company Y follows their own production plan and how accurate they perform internally. This KPI assesses the reliability of the product manufacturing process (Interviewee 3).

4.5.2.4 Overall equipment efficiency

Overall equipment efficiency (OEE) is another internal KPI at Company Y, which measures how well the production lines are utilized. OEE serves Company X in evaluating if production lines utilize capacity efficiently. If not they generate high costs and at the same time do not produce enough to cover the costs. OEE estimates the productivity of assets, using data generated from Company Y's own internal manufacturing system (Interviewee 3).

4.5.2.5 Overdue invoices

Overdue invoices measure the value of unpaid invoices that are older than 60 days. These are invoices Company X is due to pay to Company Y. The aim is to have zero overdue invoices. This KPI evaluates the financial efficiency (assets) of the sourcing process (Interviewee 3).

4.5.2.6 Sourcing costs

Sourcing costs measure the cost of the outsourced manufacturing of Product X products to Company Y. Sourcing costs include, among others, supplier pricing deviation, which analysis if the supplier is invoicing the company at a different price to what was agreed. Supplier pricing deviation contributes to the top level KPI of cost performance, which is followed at aggregated level. Cost performance is evaluated by comparing the purchase prices to the budget set. Supplier pricing deviation is followed on a monthly basis via SAP data at product level, supplier level and commodity group level, and hence at Product X supplies chain level. The figures are reported monthly by HQ Finance, contributing to recording cost performance over a twelve month period (January-December) (Interviewees 3&10).

4.5.2.7 On-time arrival from factory to DC

On-time arrival from factory to DC measures if the goods have time wise arrived as agreed at the warehouse (Logistics service provider Y only - not Company Z) from Company Y. By following the time of arrival any delays of the transportation service can be identified (Interviewee 9). However, the lead time itself is not being monitored. On-time arrival is measured monthly and is a KPI estimating reliability of the IB transportation service (Internal company report on Logistics service provider Y in feed KPI, 2014).

4.5.2.8 Non-conformity notification/supplier

Non-conformity notification (NCN) measures all the notifications per supplier. NCN is divided into NCN concerning truck and receiving. NCN truck monitors the amount of notifications concerning damaged goods, goods not ordered, missing goods, too many/few products and problems with the barcodes. NCN receiving follows issues of delays, advanced shipping notifications (ASN) not given to Logistics service provider Y and communication errors. NCN is measured at a supplier level; hence it is not possible to see which notifications are specifically related to Product X products (Internal company report on in feed non-conformity KPI, 2014).

4.5.2.9 Damaged goods/supplier

Damaged goods per supplier measures the percentage of transport boxes (trps) that arrive misshapen at the warehouse of Logistics service provider Y from the factory. This is followed by comparing the amount of broken trps received to the total amount of trps. The cause for damaged goods upon arrival can be chipped, wet, dirty or open packages or ripped labels. The amount of damaged goods is reported monthly and this is a KPI also measured at a supplier level, not at the level of the Product X supply chain (Internal company report on Logistics service provider Y in feed KPI, 2014).

4.5.3 Delivering KPIs

Company X measures the performance of the delivering process using five KPIs; order to cash management, service complaints, product complaints, telephony, and returns and express deliveries. These KPIs are all followed monthly via SAP data. All delivering KPIs are the same for every European market. Review reports for each market are issued from the respective customer service center (CSC). Service and all product complaints contribute to complaints per million (CPM).

4.5.3.1 Order to cash management

Order to cash management (OTC) measures how many orders and order lines have been processed by the CSC, and how many times an order has been processed until it is completed. Further, OTC monitors the number of credit and debit notes, their value and the reasons why Company X needs to credit money or re-invoice a customer (Interviewee 4). Credit and debit notes can be related to a pricing error made by the CSC, a picking error at warehousing or goods damaged during transportation among other things. Overall, OTC is a metric of reliability of the order handling (Internal company report on KPI base, 2014).

4.5.3.2 Service complaints

Service complaints measures three different types of incoming complaints to the CSC that are related to any service issue; customer complaints, internal reporting complaints and customer request complaints. Customer and internal reporting complaints are generated from any service issue that is related to internal processes, like transportation, warehousing or sales. Some examples of customer service complaints could be delayed shipment, wrong address or missing documents. Customer request complaints on the other hand are service complaints related to special customer demands, such as express deliveries or other extraordinary requests

(Interviewee 4). The CSC team calculates the number of service complaints and examines how Company X was contacted by the customer, where the problem was identified by them, as well as what the complaint was about. They also monitor the number of service complaints closed down and their closing time. Service complaints are a measure of reliability of order handling. Service complaints closing time however is a measure of responsiveness (Internal company report on KPI base, 2014).

4.5.3.3 Product complaints

Product complaints measure all incoming complaints to the CSC that are related to any product issue. A product complaint is not necessarily connected to a product default; it can be related to some change of the product's characteristics that the customer is not happy with, the texture for instance. It is of high importance and value for the company that the reason for customer dissatisfaction is analyzed and taken seriously into account (Internal company report on KPI base, 2014).

Product complaint closing time is also followed. When it comes to antiseptics, which are produced by a contract manufacturer, any manufacturing default usually takes longer time to process than the normal set target (days to get back to the customer). That is, mainly because Company Y is not so efficient in terms of responses to product complaints. The response lead time is even further prolonged since, as already mentioned earlier, most of the product complaints are automatically perceived to be connected to a manufacturing default until proven otherwise. Thus, Company Y first has to check if the product complaint actually is a manufacturing complaint and then continue accordingly. Product complaints are measuring reliability of order handling and product complaints closing time is a metric of responsiveness (Interviewee 4).

4.5.3.4 Telephony

Telephony measures the responsiveness (service level) to incoming calls by calculating the number of calls answered, the time it takes to process them and the number of abandoned calls (Interviewee 4). The source of each call is also examined. The most important customers have their own free numbers to contact CSC, which makes tracking and measuring transparent on these customers (Internal company report on KPI base, 2014).

4.5.3.5 Returns and express deliveries

Returns and express deliveries measure the percentage of return and express shipments to the customers, compared to the number of normal orders. Each return and express delivery is categorized according to the reason it happened in the first place. Returns evaluate the reliability of the returns process, whereas express deliveries assess the flexibility of order handling (Internal company report on KPI base, 2014).

4.6 Summary of Product X KPIs

Product X supply chain KPIs and activities are summarized in the table below (Table 3). The current KPIs are allocated under each basic characteristic (performance attributes, processes, primary and secondary metrics) as presented in the theoretical framework in chapter 2.5, based on their definition already discussed. The table includes only the Product X specific KPIs and excludes the general BSC KPIs that measure supply chain performance at aggregated level. Hence, total supply chain costs, total supply chain costs as percentage of sales and obsolete/scrapping costs are not included. FTC and transportation lead time are neither taken into consideration since they are followed by country/flow, not by supply chain. Further, NCN and damaged goods upon arrival are also left out, since they are measured per supplier and thus it is not possible to analyze their share at the Product X supply chain level. Still, all KPIs presented will be considered in the review of the theoretical framework section as potential metrics that could be proposed in the final measurement framework. Additionally, regarding the two investigated flows (Country A and Country B) there were no major differences found in measuring their performance. On-time arrival from factory to DC, however, is only monitored for the Country A flow.

Table 3 assists in comparing the proposed theoretical model and the current measurement framework of Product X supply chain, and guides in developing the final framework which will be Product X specific. All the KPIs presented in the previous sections of this chapter are summarized in a table which is available in Appendix 4.

COST	AGILITY	RELIABILITY	RESPONSIVENESS	ASSETS	Processes
		Order line completeness (OLC)			
PLAN	PLAN	PLAN	PLAN	PLAN	*Demand forecasting, inventory and distribution requirement planning*
		Order line availability (OLA)		Tied-up capital (TUC)	
		Forecast accuracy (BIAS,PLIX)			
		Backorders			
SOURCE	SOURCE	SOURCE	SOURCE	SOURCE	*Ordering, supplier evaluation, production, quality assurance, packing, release, IB transportation*
Sourcing cost		Supplier capability (OTIF)		Overall equipment efficiency (OEE)	
		Plan attainment		Overdue invoices	
		On-time arrival from factory to DC			
		Product manufacturing complaints			
DELIVER	DELIVER	DELIVER	DELIVER	DELIVER	*Warehousing, order handling, OB transportation, invoicing, returns*
	Express deliveries	OTC (Debit/Credit notes)	Telephony		
		Returns	Complaints closing time		
		Service complaints			
		Product complaints			

Table 3: *Summary of current Product X KPIs (own construction)*

4.7 Current issues

Company X is mainly a medical device product manufacturer; hence the company does not have a lot of experience when it comes to selling pharmaceuticals. In fact, Company X is perceived not to be properly set-up and resourced for that type of business. Antiseptics is only a small part of the business for Company X and the company has been struggling to promote the Product X products further in the market, since the total market is rather saturated. Overall, it seems that Company X is facing problems mainly on the production side, especially in terms of quality and stability. Most of the backorders are due to factory-related reasons, variations in demand and unavailability of stock. Quality problems, missing components, limited production capacity, and insufficient replenishment, sales higher than forecast and safety stock not aligned to demand are some typical explanations for backorders. On the contrary, the transportation services that Company X outsources to 3PLs seem to be a smaller issue, but reliability could still be improved.

4.7.1 Forecasting

There are regular cases where forecasting has not been accurate and sales have been higher than predicted. This has resulted in huge backlogs, especially since Company X normally places main orders to Company Y once a month and can only fine-tune them afterwards. It is felt that Product X is placed rather low in the priority and lacks clear ownership, which leads to inaccurate forecasts, as forecasting techniques are vague and emphasis of the sales units is put elsewhere. Lack of forecasting accuracy for Product X is also due to unreliable historical data, which serves as the basis for forecasts. Company X has faced many supplier problems since the second half of 2012 when products could not be produced as required. Demand has been higher than supply and there has been periods of no supply at all. The variance of demand has led to untrustworthy historical demand data, showing too small demand figures. Since forecasting is based on historical data, trends and patterns, this has led to inaccurate forecasts. Hence, predictability has shown to be more difficult to estimate for Product X than for other product groups (Interviewees 1,2,5&6).

Further, variations in demand depend a lot on the type of demand or customer; spot purchases versus established consumers. Spot purchases are very volatile since customers order less regularly and they are not very loyal to suppliers, whereas more established consumers in the Country A market, order regularly and place more predictable orders (Interviewee 6).

4.7.2 Production

The Product X product range is mainly manufactured by mixing chemicals. This is accompanied by high complexity, as science-based chemicals can sometimes react differently and unpredictably when mixed together. Since late 2011 - early 2012 medical auditing has revealed a lot of manufacturing and supply issues stemming from Company Y. Many product batches have been blocked, rejected or even scrapped during that time due to contaminated plastic bottles from metal particles, mistakes in the formulation of the chemical compounds and inability of proving the disproportions between the volumes of initial ingredients used and the level of those the end products contain. This has in turn led to delays in the Product X supply chain with long backorder lists and low service levels, as Company X has failed to deliver to end-customers

(Interviewees 2&3).

Moreover, due to the new requirements of the Medicine and Healthcare Products Regulatory Agency (MHRA) there have been some changes in rules and regulations of the healthcare industry. More specifically, out of the bulk raw material delivered by one vessel Company Y is now allowed to produce only two different products. Put in other words, the maximum stock keeping units (SKUs) to share a batch of raw material is now only two. This has totally changed the core business for Company X causing batch size issues, which has in turn led to time and cost problems. That is, Company X has been pressed to increase batch sizes and thus has been forced to “kill” some of the smaller products. This complicates the ordering process even further for Company X, which is also suffering from long supply lead times. Purchase orders (PO) are given only once a month to Company Y and the products are received 2-3 months later. There have also been some incidents with the packaging, where products have arrived damaged at the warehouse in Country C (Interviewees 1&3).

4.7.3 Warehousing

Besides production problems there have been many warehousing issues. That is, proper storage capacity is not sufficient. For instance, the warehouse in Country C does not have enough storage space for pharmaceuticals, which is the reason for the main bottleneck of the Product X supply chain in the Country A at the moment. The products are not delivered as promised leading to huge backlogs. There have been cases where Company X has asked Company Y to take care of the storage of the finished goods as they have been incapable of doing it themselves. That is something which is not included in the contract between Company X and Company Y, thus is merely done by Company Y as a favor. This illustrates the existing lack of clear service level agreements (SLAs), for example between suppliers and warehouses, which in turn indicates the absence of full integration of the Product X supply chain. Furthermore, storage of pharmaceuticals under special conditions concerning temperature and hygiene makes warehousing even more complicating. In some markets, such as France, there is a stipulation that the products targeted to the Country B market need to be warehoused in that country (Interviewees 1,3&5).

4.7.4 Transportation

There are also transportation problems that arise. Inbound/outbound transportation is not always reliable and quick enough, and it seems that Company X is not good enough at predicting the needs of logistics, including transportation. All the finished products are sold to Company X ex-works, which means it is the responsibility of Company X to organize the transportation of the goods to various warehouses. Company X uses 3PL company Logistics service provider X for transportation to Country A and incurs currently issues due to unreliable deliveries, which is very frustrating for the local market. At present, the finished goods wait too long to be picked up and lead times are not reliable. However, as already mentioned, this is an area, which is currently not being measured at supply chain level and hence it is difficult to grasp a whole picture of the situation. There is also a rather new requirement to use temperature controlled trucks, which is a challenge as such. Further, there have been issues with transportation documentation, in particular with missing delivery notes (Interviewee 9&12).

4.7.5 Invoicing

Additionally, Company X is experiencing some issues with the invoices. As the situation is now, there can be only one receipt/invoice for each purchase order (PO). After receiving the first shipment the PO is matched with that and closed down. However, POs often contain more items that do not arrive at the same time. Once the remaining items are delivered, there are no matching POs open and a mismatch between POs and invoices is being created. This causes a lot of unnecessary trouble for the company, which costs time and money (Interviewee 7).

5. Data analysis

5.1 Comparison between current and theoretical measurement frameworks

Current measurement of the Product X supply chain is done by main functions (plan, source, make/contract manufacturing, deliver) and covers some of the areas suggested in the theoretical measurement framework. Company X uses a procurement scorecard to measure performance of the Product X supply chain, but a clear and specific measurement framework is missing. The company follows a number of KPIs at Product X level monitoring mostly reliability, but lacks metrics to evaluate the overall performance of the E2E Product X supply chain. The measurement is not integrated with the supplier (Company Y) or with the distributor (Company Z in Country B), but all actors follow their own performance. This is to say the measurement lacks true E2E supply chain integration. A more explicit description of the differences and similarities between the proposed theoretical measurement framework and the current one follows.

5.1.1 Costs

Out of the five performance attributes suggested by the theoretical measurement framework costs are followed at the top level and metrics are similar to the ones presented by the theoretical measurement model. Almost all of the costs are however tracked at aggregated level, including the whole surgical division, and therefore it is not possible to see which part is due to Product X supply chain. In specific, supply chain management cost, obsolete/scrapping costs and inventory costs are measured by divisions and not at the supply chain level.

Looking at the processes and starting from the planning and sourcing phases, none of the metrics proposed in the theoretical model are used. Company X is following supplier pricing deviation, as part of sourcing costs, which is not included in the theoretical framework as a suggested metric. Sourcing costs however are included. Further, as mentioned earlier, transportation (IB and OB) costs and warehousing costs are being measured but not at supply chain level, even though they accumulate a major share of the costs since antiseptics require temperature controlled vehicles and warehouses. Manufacturing costs are neither being followed.

COSTS					
THEORETICAL	*Primary metric*	E2E SUPPLY CHAIN COST			
CURRENT HIBI		-			
	Process	PLAN	SOURCE	MAKE	DELIVER
THEORETICAL	*Secondary metrics*	Information processing cost	Sourcing cost	Manufacturing cost	OB transport cost
		Inventory carrying cost	IB transport cost		Warehousing cost
CURRENT HIBI	-	-	Sourcing cost	-	-

Table 4: *Comparison of Costs (own construction)*

5.1.2 Agility

Key characteristics of an agile organization are adaptability and flexibility. Company X follows neither one of them at top level. The only metric of agility that Company X currently uses is express deliveries. The theoretical model includes metrics measuring response time to external and internal changes, like time to adjust sourcing and manufacturing product volumes and mix. These are currently not measured at all at the Product X supply chain level. Additional metrics for agility are time to market, time to adjust supplying and manufacturing frequency, manufacturing change-over time and time to adjust deliveries according to special customer needs.

AGILITY					
THEORETICAL	*Primary metric*	RESPONSE TIME TO CHANGES			
CURRENT HIBI		-			
	Process	PLAN	SOURCE	MAKE	DELIVER
THEORETICAL	*Secondary metrics*	Time to market	Time to adjust product vol+mix	Manufac. change-over time	Time to adjust to special demand
			Time to adjust supply freq.	Time to adjust manuf. vol+mix	
				Time to adjust manuf. freq.	
CURRENT HIBI		-	-	-	Express deliveries

Table 5: *Comparison of Agility (own construction)*

5.1.3 Reliability

The theoretical framework proposes as primary metric to measure perfect order fulfillment, which can be measured in more detail by various secondary metrics. Considering Product X supply chain this is done by following order line completeness (OLC) throughout the supply chain. However, OLC measures performance only until the warehouse in Country C and does not pay attention to final deliveries to end-customers.

Forecasting plays the biggest role in the planning phase, as it is an important tool to anticipate demand and adjust supply accordingly. At Product X level it is evaluated by measuring forecast accuracy (BIAS) and planning index (PLIX). BIAS and PLIX are measured in two versions: one month and three months average. This is congruent to the theoretical framework that recommends following forecast versus sales. The theory also suggests including forecasting volatility, since high volatility makes planning and right time production very challenging. Further, the framework proposes to monitor forecast versus order and not only forecast versus sales. Order availability is measured accordingly by order line availability (OLA) and stockout rate by backorders (BO). These are in line with metrics suggested by our framework.

Looking at the sourcing phase, supplier fill rate is partly measured by on time-in full (OTIF), which is a metric to evaluate supplier performance. On time arrival from factory to DC is followed as well, but not on-time departure from factory. Company X does not evaluate making phase separately, but the metrics used within contract manufacturing are compared to the ones proposed for making in the theoretical framework. On time production, as proposed by the model, is not measured as such, neither quality tracking. However, plan attainment is evaluated by measuring actual production versus planned production, which is a good estimate for on time production. Complaints related to products manufacturing are being followed giving an approximation of the level of production quality and hence function as quality monitoring.

At the delivery phase, on-time arrival from DC to customers is neither evaluated, nor on-time departure from DC. Faultless delivery notes/invoices are not monitored either. In contrast, Company X measures order to cash management (OTC), the amount of credit/debit notes and returns to estimate the delivery reliability of the Product X supply chain. Further, service and product complaints are followed to analyze the reliability of deliveries. These metrics are not presented in our framework.

RELIABILITY					
THEORETICAL	Primary metric	PERFECT ORDER FULLFILMENT			
CURRENT HIBI		ORDER LINE COMPLETENESS (OLC)			
	Process	PLAN	SOURCE	MAKE	DELIVER
THEORETICAL	Secondary metrics	Forecast vs order	Supplier fill rate	On-time production	On-time arr at end-customer
		Forecast vs sales	On-time arr at DC	Quality tracking	On-time dep from DC
		Forecast volatility	On-time dep from factory		Faultless del notes/invoices
		Order availability			
		Stockout rate			
CURRENT HIBI	Secondary metrics	OLA	Supplier capability (OTIF)	Plan attainment	OTC (Credit/Debit notes)
		Forecast accuracy (BIAS, PLIX)	On-time arrival at DC	Product manuf.complaints	Returns
		Backorders (BO)			Service complaints
					Product complaints

Table 6: *Comparison of Reliability (own construction)*

5.1.4 Responsiveness

The theoretical framework presents order fulfillment cycle time (CT) as a primary metric, which is further measured by various cycle and lead time metrics. At the moment these are not applied neither as primary, nor as secondary metrics within Product X supply chain. For instance, transportation lead time (LT) is only being followed by flows, but not by products. The only identical metric is customer complaints closing time, which measures how fast customer complaints are being handled and resolved. This is followed at Company X by monitoring if the complaints have been answered within stipulated timeframes. Another secondary metric being used, which is not proposed by the theoretical framework, is telephony. It measures the responsiveness to incoming calls. The theoretical framework further suggests to monitor planning cycle time, order lead time, purchase order cycle time, manufacturing lead time, inbound and outbound transportation lead time.

RESPONSIVENESS					
THEORETICAL	Primary metric	TTL RESPONSE TIME TO CHANGED CONDITIONS			
CURRENT HIBI		-			
	Process	PLAN	SOURCE	MAKE	DELIVER
THEORETICAL	Secondary metrics	Planning cycle time	Purchase order CT	Manufac. LT	OB transp. LT
		Order lead time	IB transp. LT		Complaints resol. time
CURRENT HIBI		-	-	-	Telephony
					Complaints closing time

Table 7: *Comparison of Responsiveness (own construction)*

5.1.5 Assets

Assets measure the time it takes to receive payment from the customer for the investments made. In the theoretical framework cash-to-cash cycle time and return on fixed assets are suggested as primary metrics, which are not followed by Company X at the moment. The proposed metrics for the planning phase include total inventory days of supply and obsolete inventory. Tied-up capital (TUC) is currently being measured at Company X by inventory days of supply and includes factory stock, stock in transit and warehouse stock. Obsolete inventory is being monitored at divisional level, not at the Product X supply chain level. Economic order quantity is not followed at all, whereas capacity utilization is estimated by overall equipment efficiency (OEE). Moreover, overdue invoices are monitored, which is in line with the proposed metric, accounts payable. On the contrary, warehouse facility and transportation space utilization (IB and OB) are not evaluated by Product X supply chain level, nor are accounts receivable.

ASSETS					
THEORETICAL	*Primary metrics*	CASH-TO-CASH CT			
		RETURN ON FIXED ASSETS			
CURRENT HIBI		-			
	Process	PLAN	SOURCE	MAKE	DELIVER
THEORETICAL	*Secondary metrics*	Inventory DOS	EOQ	Capacity utilization	Wareh facil utiliz
		Obsolete inventory	Transp. (IB) space utilization		Transp. (OB) space utilization
			Overdue invoices		Accounts receivable
CURRENT HIBI	*Secondary metrics*	Tied-up capital (TUC)	-	OEE	-
			Overdue invoices		

Table 8: *Comparison of Assets (own construction)*

5.2 Review of the theoretical framework

Empirical study at Company X offered a lot of insights into the Product X supply chain. Having interviewed various stakeholders we identified planning, sourcing (contract manufacturing) and delivering as relevant main processes concerning the Product X supply chain. Even though making as a process is not internal for Company X, it is of crucial importance to the E2E Product X supply chain and should be regarded as one of the areas to include into the measurement framework. This is especially the case concerning Product X, since many current issues are related to production (making). Introducing metrics to measure reliability and responsiveness of contract manufacturing (making) would help to stabilize the flow, and diminish large backorders. The measurement should be part of the contract manufacturing practices, and metrics and targets should be set up in cooperation with Company Y, as well as with the 3PLs. These goals could then function as basis for SLAs.

5.2.1 Performance attributes

The performance attributes suggested by the theoretical framework (costs, agility, reliability, responsiveness, assets) seem to be relevant for Company X. They cover several aspects of measurement and ensure a balanced approach.

5.2.1.1 Costs

Costs are indispensable in any measurement framework to assess the financial performance. For Company X huge backlogs of antiseptics have caused high extra costs. According to the strategy of the Product X supply chain, product availability and customer service level are to be improved at optimal cost, indicating the importance of cost control. Thus, measuring costs is an integral part of the measurement framework concerning Product X and should be done at the supply chain level to get a transparent picture of the whole situation.

5.2.1.2 Agility and responsiveness

Agility and responsiveness have become more important in the volatile market environment. Customer satisfaction is a top priority for Company X, however, flexibility and adaptability are hardly measured at all. Lead times and distinct cycle times are neither being followed, even though they are key parameters in analyzing responsiveness. It is argued that agility and responsiveness are critical dimensions, and should therefore be employed in the measurement model.

5.2.1.3 Reliability

Reliability, the ability to perform the tasks as expected, has gained the most attention concerning Product X. Various forecasts, as well as supplier performance metrics, are used to assess the activities. Reliability is a core measurement attribute on the way to stabilize the supply chain and hence uttermost important.

5.2.1.4 Assets

Assets are pertinent for Company X in order to improve the availability and at the same time be financially efficient. The target is to reach high customer service level but at the same time minimize tied-up capital. There is always a trade-off between these two aspects and it is essential to be able to measure the consequences of each parameter.

5.2.2 Metrics

The proposed metrics regard different phases of the supply chain and are to some extent similar to the existing metrics. The theoretical model proposes quite many new metrics that are not used at the moment by Company X. Most of the existing metrics are valued as useful, but it is suggested to deliberately introduce new ones to get a more balanced view. In order not to have too many metrics we have tried to reduce the number of metrics to the most relevant ones and therefore removed some of the metrics we presented in the theoretical framework.

There was only one primary, top level metric recognized at the supply chain level, namely order line completeness (OLC) that evaluates reliability of the Product X supply chain. However, OLC misses the holistic view of the supply chain, since the downstream flow from warehouse to end-customers is not included. Moreover, OLC does not measure lost sales. For instance, if Customer A (one of the biggest customers in Country A that does not accept backorders) cancels an order, it would not show in OLC. Therefore, we recommend to use perfect order fulfillment instead. Other primary metrics are E2E supply chain costs, total response time to changed conditions, total order fulfillment cycle time, cash-to-cash cycle time and return on fixed assets.

5.2.2.1 Planning

Planning is a vital phase of any supply chain and especially the role of forecasting. This is an area in which Company X is experiencing problems in particular concerning Product X, since the actual sales have been significantly higher than forecasts, leading to huge backlogs. The emphasis should be on forecasting functions serving as a basis for the whole supply chain planning, including sourcing, contract manufacturing, warehousing and inventory management, among others. Therefore, it is argued to measure not just forecast versus sales, but also forecast volatility. Forecast volatility should be as low as possible for the stability of the supply chain. Forecast versus orders is left out, since it was felt not to be the most suitable metric for the Product X supply chain. Customers are usually re-ordering many times if not receiving the products at once and this distorts the metric. Currently Company X uses one month and three months average for estimating BIAS and PLIX (forecast versus sales). However, the one month version is not very accurate. As Company X serves its customers on specific days, for instance Mondays, in case there are many Mondays in a month the one month version will measure higher sales than in a month with less Mondays leading to volatile forecast measures. Thus, the three months average would be a more advisable metric. Additionally, inventory availability should be followed by measuring order availability and stockout rate. This is crucial in the case of the Product X since backorders are extremely high.

Further, it is suggested to measure planning cycle time and order lead time, as these are key metrics of responsiveness. Long cycle and lead times add uncertainty to the supply chain, which in turn decreases stability. Time to market is left out from the reviewed measurement framework, since monitoring new product development and introduction time is not perceived as the most relevant for Product X at the moment. Additional planning phase metrics that should be applied are obsolete inventory and total inventory days of supply. The first one increases cash-to-cash cycle time. Disposal of obsolete antiseptics is rather challenging, and contribute to higher total inventory costs and lower returns on fixed assets. The latter (total inventory days of supply) should be included, because it is the major contributor to tied-up capital.

Out of financial metrics we prioritize inventory carrying costs. Inventory carrying costs should be followed at the supply chain level, especially when it comes to antiseptics, as the special temperature and hygiene requirements for the Product X products raise inventory carrying and warehousing costs significantly. With the relatively high amount of backorders, partly due to volatile demand, there could possibly be a larger safety stock needed, which would improve the service level, but on the other hand increase costs. In order to analyze the trade-off between costs and responsiveness there should be an estimate of the inventory carrying costs at the Product X supply chain level. In the theoretical model it is proposed to measure information processing costs. Historically the focus has not been on IT costs, with a lot of the inputs (such as submitting purchase orders) being processed manually. This is however an essential metric if the Product X supply chain is to become more responsive and integrated downstream and upstream, requiring transparent exchange of information and compatible IT systems throughout the entire supply chain. The metric is though excluded from the reviewed measurement framework, as at this point the focus is on stabilizing the Product X supply chain, keeping the model simple, and only including metrics that measure current processes and activities.

5.2.2.2 Sourcing

When it comes to sourcing, supplier delivery performance should have a priority focus. Therefore, it is recommended to include supplier fill rate as metric, instead of OTIF (on time-in full), as it covers more aspects of supplier performance (right quantity, product, documentation, date, condition). Purchase order cycle time estimates the responsiveness and should be introduced as well. At the moment it seems to be very long, but exact times are not known. The longer the cycle time, the more uncertainty about the demand, the higher the needed inventory and safety stock, and the more costs involved.

Agility is a requirement for all modern supply chains and so also for Product X, as high customer service level is one of the main targets and a prerequisite to succeed in the market. Thus, it is suggested to include metrics for measuring agility; time to adjust sourcing product volumes and mix, and time to adjust to supplying frequency. Time to adjust sourcing product volumes and mix is recommended as a metric between Company X and its suppliers. It is found to be essential for the continuity of the production and hence for the stability of the whole Product X supply chain. Company X submits purchase orders to Company Y once a month, which is at the moment a fixed ordering frequency. If Company X ordered more dynamically, which is recommendable, time to adjust supplying frequency could be another relevant metric for measuring agility of sourcing.

Transportation is an area that deserves attention. Inbound transportation costs, transportation lead time, on-time arrival at DC, on-time departure from factory and transportation (IB) space utilization are recommended as metrics. IB transportation costs will increase dramatically after new regulations of requirement for temperature controlled trucks. These costs should be allocated to products and not to the whole division (surgical) to get a real picture of the costs incurred. It is also essential to include a metric for transportation space utilization, since high fill rate is desirable due to the same cost reasons. Transportation lead times are felt to be somewhat unreliable and goods are not always being picked up and delivered on-time. In order to find out the root causes for delays, transportation lead time, on-time arrival and departure should be evaluated. Finally, sourcing costs should be included into the model, even though there are not many possible alternative suppliers to take into consideration. Besides product prices, the emphasis should be on cost saving initiatives the supplier is capable of achieving in the long term. One more secondary metric proposed is overdue invoices (accounts payable) contributing to cash-to-cash cycle time.

Generally, it would also be beneficial for Company X to update Supplier Performance Measurement (SPM) system to apply to contract manufacturing and hence to be able to analyze the efficiency of procurement for Product X supply chain.

5.2.2.3 Making

As mentioned in the beginning of this chapter it is proposed to include making as a separate phase into the measurement framework, notwithstanding that it is missing internally. Contract manufacturing plays a key role in Product X supply chain and collaboration with Company Y is vital. Plan attainment (on-time production) and OEE (capacity utilization) are suggested to be included in the framework as such, but instead of focusing on product manufacturing complaints it would be advisable to take a more proactive approach and apply quality tracking (free from errors) as a metric. In addition to these, manufacturing lead time, manufacturing change-over time, time to adjust to manufacturing product volumes and mix, and time to adjust manufacturing frequency should be measured to grasp a picture of the responsiveness and agility. However, since MHRA has stipulated new rules and regulations concerning, among other things, the number of different products that can be produced out of one batch of raw materials, time to adjust to manufacturing product volumes and mix is a controversial metric to apply in this context. Finally, manufacturing costs should be monitored to incorporate the cost aspect into the picture.

5.2.2.4 Delivering

There were quite many new metrics introduced in the area of delivery, since customer service level is a top priority for the Product X supply chain. Company X uses currently a large number of metrics for evaluating the delivery process, among them service and product complaints, and their resolution time (complaints closing time). This illustrates that Company X is more reactive at the downstream of the Product X supply chain. The reviewed framework aims to take a more proactive approach and hence introduces time to adjust deliveries according to special customer demand, on-time departure from DC, on-time arrival at end-customer, outbound transportation lead time and faultless delivery notes/invoices as new, appropriate secondary metrics measuring agility, responsiveness and reliability. Already mentioned existing metrics are kept and included into the final measurement framework. Time to adjust deliveries according to specific customer requirements is replacing express deliveries as it takes a broader perspective. The emphasis of proposed metrics is in evaluating transportation, which is one of the areas causing problems at the moment. Transportation performance has not been assessed in detail, since there has not been specific metrics for this in the current measurement system.

Moreover, transportation (OB) and warehousing costs are suggested as suitable financial metrics. Estimating these at the Product X supply chain level would be even more important in the future with the upcoming transportation requirements. Antiseptics will demand temperature controlled transportation, which is a significant cost driver causing extra expenses that should be allocated correctly. Otherwise it is very difficult to understand and manage the root causes of costs. The same concerns warehousing costs. Product X products require temperature controlled warehouses, which means the costs are higher than for some other products and it would be recommendable to follow this metric at the supply chain level. Taking a look at assets, it is recommended to measure accounts receivable since they tie-up capital and hence influence cash-to-cash cycle time. Transportation space and warehousing facility utilization are further proposed as metrics contributing to evaluation of the efficiency of assets, which is another area lacking measurement. Lastly, telephony is not included in the final framework as it is not considered as one of the most important metrics estimating responsiveness and hence would not add any value.

Having reviewed the theoretical measurement framework, according to the needs of Company X, it is argued that the final model (Table 4) should be, as such, applicable to function as a measurement framework for the Product X supply chain. Furthermore, the proposed metrics are relevant in measuring the E2E Product X supply chain performance.

COST	AGILITY	RELIABILITY	RESPONSIVENESS	ASSETS
E2E SC Costs	Ttl Response Time to changed conditions	Perfect Order Fullfilment	Ttl Order Fullfilment Cycle Time	Cash-to-cash Cycle Time, Return on Fixed Assets
PLAN	*PLAN*	*PLAN*	*PLAN*	*PLAN*
Inventory carrying costs		Forecast vs sales (BIAS, PLIX)	Planning cycle time	Ttl inventory days of supply (TUC)
		Forecast volatility	Order lead time	Obsolete inventory
		Order availability		
		Stockout rate (BO)		
SOURCE	*SOURCE*	*SOURCE*	*SOURCE*	*SOURCE*
Sourcing costs	Time to adjust product volumes and mix	Supplier fill rate	PO cycle time	IB Transportation space utilization
IB transportation costs	Time to adjust supplying frequency	On time arrival from factory to DC	IB transportation lead time	Overdue invoices (accounts payable)
		On time departure from factory to DC		
MAKE	*MAKE*	*MAKE*	*MAKE*	*MAKE*
Manufacturing costs	Manufacturing change-over time	On-time production (plan attainment)	Manufacturing lead time	Capacity utilization (OEE)
	Time to adjust manufacturing product volumes and mix	Quality tracking (free from errors)		
	Time to adjust manufacturing frequency			
DELIVER	*DELIVER*	*DELIVER*	*DELIVER*	*DELIVER*
OB transportation costs	Time to adjust deliveries according to special customer demand	On time arrival from DC to end-customer	OB transportation lead time	Accounts receivable
Warehousing costs		On time departure from DC to end-customer	Complaints resolution time	Warehousing facility utilization
		Faultless delivery notes/invoices		OB Transportation space utilization
		Service complaints		
		Product complaints		

Table 9: *Reviewed Measurement Framework (own construction)*

5.3 Challenges of measuring

According to the theory one of the most common pitfalls is to sub-optimize and not to apply cross-organizational thinking. This is also the case concerning the Product X supply chain. As mentioned earlier, the current measurement system is internal and not integrated with the suppliers or customers. In other words, there is a lack of true cross-organizational integration and from the measurement point of view the Product X supply chain is not being seen as one entity. This indicates quite low level of collaboration, for instance between Company X and Company

Y. They both have their own metrics and KPIs and are not truly sharing the performance information. They do meet once a month to review the operations and make sure there is enough capacity by comparing the estimated demand to the production capacity. Company X submits once a month a forecast to Company Y, but order books are then revised weekly according to updated customer demand. That indicates that there is not a long visibility of the orders. Moreover, a close collaboration with downstream partners in the E2E Product X supply chain is missing, especially in the Country B market where Company Z acts very independently.

Currently used metrics are more quantitative of nature, which is a typical, rather easy approach to performance measurement. However, in order to succeed in the future companies need to become more responsive and agile, and this demands more qualitative metrics. Company X has been measuring only some aspects of the Product X supply chain performance, mainly reliability, but is still performing very unreliable. The metrics are disconnected from the current strategy and there is not enough analysis based on them to evaluate the overall performance of the supply chain.

One of the challenges faced during the research was the fact that everyone seemed to have divergent views of the main issues and problems within the Product X supply chain. Also, the strategic emphasis of the Product X supply chain was understood slightly differently. The headquarters emphasized the need for effectiveness and efficiency in stabilizing the supply chain, whereas according to other stakeholders and involved persons the main target is the high service level towards the end-customers. This evidences lack of communication and clear objectives, as well as loss of supply chain context, which also belong to the typical difficulties.

6. Conclusion

This research paper is a case study and answers the stated research question of which supply chain performance measurement framework and metrics are relevant for Company X in measuring the performance of the end-to-end Product X supply chain. The Product X supply chain is currently perceived as unstable and unreliable, partly because of the inconsistent measurement and irrelevant metrics, but also due to the lack of true cross-organizational integration of measurement systems.

The study develops a specific framework for E2E Product X supply chain performance measurement. This framework consists of performance attributes and metrics, and is based on some of the most cited measurement models. The proposed framework comprises five performance attributes, cost, agility, reliability, responsiveness and assets, which are found to be the most suitable. They take financial and operational aspects into consideration, as well as customer service level, and are therefore argued to give a balanced and comprehensive view of the performance. Main processes of plan, source, make and deliver are evaluated from these different angles.

The metrics are chosen according to the needs and the strategy of the Product X supply chain; to stabilize its performance at reasonable costs and to ensure high customer service level. Each performance attribute is evaluated by top level/primary metrics, which can be monitored in more detail through various secondary metrics. This structure enables the management to drill down to lower levels in order to find the root causes to problems. The effort is done to include only the most integral metrics to evaluate the performance, following the design criteria of keeping the framework simple, unambiguous, easy to measure and communicate.

Different cost based metrics contribute to the total E2E supply chain costs and should be followed at the Product X supply chain level, which is not the case at the moment. Especially transportation (IB and OB) and warehousing costs deserve more attention due to new hygiene and temperature requirements concerning transportation and storage of Product X products.

Agility and responsiveness have not been in focus, even though fulfilling customer demand and achieving high service level are expressed as main targets of the Product X supply chain. Therefore, it is argued that total response time to changed conditions and total order fulfillment cycle time should be measured, evaluating flexibility, adaptability and responsiveness. Flexibility of production and transportation is crucial in order to respond to changing customer demand. Further, long cycle and lead times add uncertainty impede the stabilization efforts and should hence be monitored as well.

Perfect order fulfillment is the basis for measuring reliability. The emphasis is in forecast accuracy, which has been one of the issues concerning the Product X supply chain. In specific, a metric for forecast volatility should be introduced in order to prevent high variation, which makes planning very challenging. Supplier fill rate is another core metric, particularly for Company X that has had many production issues with Company Y. Further, the performance of transportation (IB and OB) should be measured to estimate its contribution to reliability.

Finally, assets take a financial perspective evaluating how efficiently the current resources are used. Total inventory days of supply, accounts payable and accounts receivable contribute to cash-to-cash cycle time and should be followed. Return on fixed assets is another primary metric that falls under assets and should be monitored. As one of the discovered bottlenecks in the current Product X supply chain is the lack of warehousing space, it is essential to measure how well the warehouse facilities are utilized. The same applies to transportation space and manufacturing capacity utilization.

Overall, the Product X supply chain measurement framework assists the management of Company X to assess the performance by revealing gaps between planning and execution, and hence to identify the main issues and necessary corrective actions to be taken.

6.1 Recommendations

Before the implementation of the developed measurement framework a performance measurement team is suggested to be formed by a group of cross-organizational people that can lead the overview meetings and oversee the overall supply chain operations (Chan & Qi, 2003a; Chae, 2009). Roles and responsibilities of each supply chain group member should be well defined and communicated to gain full understanding of the supply chain context. The stakeholders should agree on mutual goals and targets for metrics, which in turn should be in line with the strategy across the whole supply chain. This prevents the suboptimization and makes sure everyone is striving after the maximum performance. As strategy and goals may change over time, metrics should be reviewed on a regular basis. Members from various organizational functions should participate in revision of the measurement framework and metrics to ensure the objectivity of the performance measurement system and suitability of metrics.

In the long term it is highly recommended for Company X to nurture cross-organizational management and infrastructure. The company needs to integrate the measurement activities with upstream and downstream partners to accomplish a truly transparent and integrated E2E supply chain, and to employ metrics accordingly. For instance, by forming cooperative partnerships with suppliers Company X can benefit from more efficient and more effective sourcing, as well as enhanced supply chain integration. Transparency of information and communication is also to be emphasized. Diaphanous exchange of market information would enable Company X to understand and forecast real customer demand, drive upstream operations accordingly, become more demand-driven and better respond to customer requirements. Investing in information systems to process needed data and especially integration of various systems, in order to enhance the measurement across different partners (Company Y, Company X, Company Z, Logistics service provider X etc.), is a challenge as such. Nevertheless, it is an inevitable necessity in today's market. The company should employ a formal method of monitoring performance of the supply chain to get as much feedback and data as possible from various activities and operations.

6.2 Suggestions for future research

More recently the attention has been drawn by researchers and practitioners into investigating supply chain performance measurement and metrics. There is an existing vast literature of theories and practices in supply chain management, and the field of supply chain performance is increasingly gaining researchers' and practitioners' attention. Still, the existing supply chain performance measurement methods and metrics have failed to provide significant assistance in improving supply chain performance; an effective framework is missing and there is no consensus about which metrics to use. Hence, further attention and more efforts are required in designing new measurement frameworks and metrics that assess performance of the supply chain as a whole (Gunasekaran et al, 2004). That is, developing performance measurement systems that enhance integration among all partners and functions of the E2E supply chain, and metrics that focus on assessment of common goals and are in line with strategy.

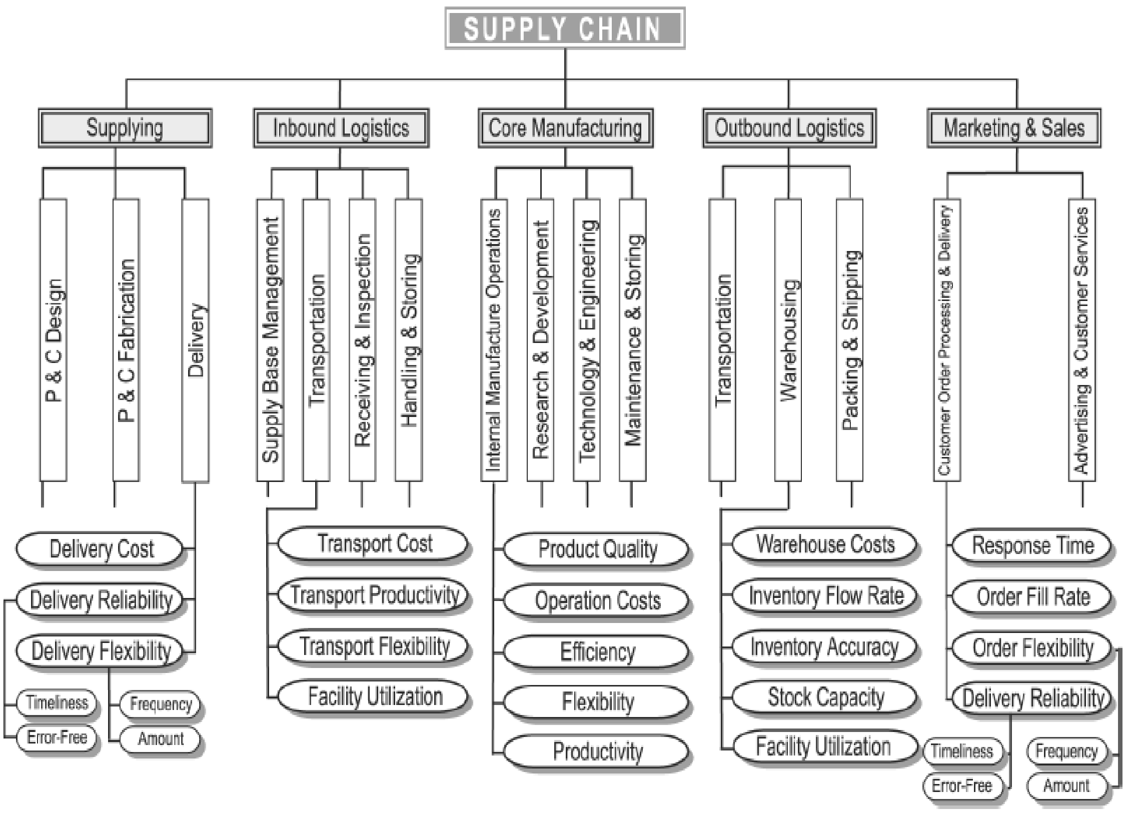
On the other hand, there is need for empirical research to test and validate the already proposed frameworks and metrics, and to analyze their contribution to outcome. That includes examination of the performance measurement frameworks proposed in this paper. Company X especially will have to implement the presented model first in order to ensure its utmost suitability. The company can take this project even one step further by implementing business process reengineering. Evaluating the current processes and activities and identifying improvement areas will simplify the overall measurement task and hence result in better outcome.

As there are no specific guidelines on how to measure and what metrics to use, an effective performance measurement method has always been under debate. Therefore, benchmarking supply chain measurement frameworks and metrics across industries is another interesting topic that requires further research. There are already attempts to find the best measurement practices and the most useful metrics, even though until now the frameworks have been very contextual (Gunasekaran et al, 2004). The SCOR model is the most advanced in generalizing measurement parameters and is the most used example as basis for other frameworks. It however remains to be seen if there will be one specific model that can be applied across industries and companies. Generalizability of the proposed theoretical performance measurement framework can be tested in terms of applicability to other supply chains within Company X as well as to other companies within the same or different business sectors.

Another growing area of interest for research is certainly the measurement and metrics of green and sustainable supply chains. Corporate social responsibility has become uttermost vital aspect of competitiveness and cannot be neglected in the future. This concerns also supply chain measurement frameworks and metrics, which are supposed to pay attention to green facts and apply metrics assessing the sustainability of supply chains.

7. Appendices

7.1 Appendix 1



Picture 9: *Chan & Qi model exemplar (Chan & Qi, 2003a)*

7.2 Appendix 2

Picture 10: *SCOR model (SCC, 2010)*

7.3 Appendix 3

Processes are based on internal company report on SEADC (2014).

7.3.1 Planning process

Planning involves tracking, measuring and evaluating the supply chain, defining and setting planning parameters, alerting, communicating and taking needed supply chain actions. All this is handled by the supply chain planning (SCP) team.

7.3.1.1 Tracking, measuring and evaluating the supply chain

Track, measure and evaluate includes APO forecasting, reviewing Mölnlycke Business Management (MBM) feedback, reviewing demand and supply summary and commercial agreements, approving MBM master plan and developing and validating products and processes.

Company X uses a 12 months' rolling forecast, which means that the number of periods in the forecast remain constant. All the other nodes of the supply chain can be notified with the results and have access to them through the SAP system. Forecasting is a snapshot captured each month as part of the Mölnlycke Business Management (MBM) process. For the Country A market forecasting is based mainly on historical data since Product Xscrub is a mature product in this market. On the contrary, forecasting for the Country B market is based on trend-historical data of 3-12 months period of time, assuming it will follow the same pattern. That is because Company X does not have any sales department dedicated to the Country B market when it comes to antiseptics.

Company X's SCP team and Company Y have monthly business overviews where they review supply. Product review, developing new products, forecasting versus capacity (i.e quality and supply issues), reconciliation, complaints and credit issues (i.e open invoices) are some of the matters they go through during the review meetings. A supply chain evaluation report is the outcome of this process.

7.3.1.2 Defining and setting planning parameters

SCP receives recommendations for MRP parameters via a project. This way, SCP defines and sets parameters according to Global Inventory Guidelines, which guides operational, tactical and strategic work related to Inventory Management and hence also to service level at Company X globally. SCP has the main responsibility for ensuring that inventory & service level targets are fulfilled through planning process across the supply chain in collaboration with relevant departments. The outcomes of this phase are the planning parameters and targets to achieve the set goals. The MRP parameters are reviewed and followed on a monthly basis.

7.3.1.3 Alerting, taking action and communicating

All this results in net supply requirements, which forms basis for material and production planning. If issues arise it must be estimated how big an effect they will cause to the entire supply chain, who will be affected and they need to be communicated to all relevant stakeholders. SAP is updated accordingly and orders prioritized if there is not enough capacity to produce the required amount.

7.3.1.4 Supply chain actions

Needed actions aim at maximizing OLC. Outcome consists of committed and confirmed supply requirements. The aim is to reach high customer service level and at the same time optimize the level of inventory and safety stock.

7.3.2 Sourcing process

Sourcing consists of ordering, production, quality checks, packaging, product release and transportation (inbound logistics).

7.3.2.1 Ordering

Antiseptics are produced under a contract manufacturing agreement, therefore Company X initiates an ordering process by order requirements and Company Y organizes material and production planning. There are certain order constraints and rules guiding the ordering process. Placing orders is an iterative procedure. Company X sends the orders once a month to Company Y. Company Y in turn reviews the orders, checks raw materials, services and indirect material availability and sends feedback to Company X on required changes. For example, there could be a request to change the quantity ordered so as to deliver in full batches. After having reviewed the feedback Company X discusses the needed change with Company Y, and both parties agree on the details of the final orders. Company Y finally confirms the agreed delivery quantities and dates, and a new purchase order (PO) report is issued by Company X. This is one whole week's procedure.

7.3.2.2 Production

Company Y is responsible for buying the raw material, producing the liquid bulk and filling it into bottles. Company X is the one that negotiates with the raw material suppliers, and passes on the price and capacity arrangements to Company Y by dictating the suppliers. In this way Company X ensures the contract liability of the end product. In other words, various suppliers and all the supplied raw materials of each batch need to be analyzed and approved. There is also a requirement to be able to track which batch of raw materials was used for which products.

7.3.2.3 Quality checks

Company Y has its own quality management system and product testing laboratories at the site. The facilities are regularly audited by medical authorities as well as by its customers and need to be approved before the packaging can take place (The Boots, 2014).

7.3.2.4 Packaging

Company Y is responsible for packing the products. The only exception to this is packing of ampoules. For ampoules, Company Y just accounts for producing the liquid bulk, which is then sold ex works to a packaging company called Holopack for bottling. Procurement of packaging materials works exactly the same as with raw materials. Company Y is responsible for ordering and buying the packaging material whereas Company X dictates the suppliers to Company Y. The filled and packed end-products are then sold ex works to Company X.

7.3.2.5 Release of products

Since Company Y has long experience of producing highly regulated pharmaceuticals, Company X has outsourced quality management of antiseptics to Company Y and does not have any external quality checks. The QP issues a certificate of analysis for each batch ensuring product quality before the goods are ready for release.

7.3.2.6 Transportation (inbound logistics)

Company X is in charge of organizing the transportation since all the products are sold ex works. The finished products are transported by Logistics service provider X to 3PL warehouses, sub-contractors or straight to external distributors. The main warehouses and distribution centers are in Country C (Country C), Sweden (Landskrona) and France (Lyon). Pharmaceuticals on the Country B market are distributed by a sub-contractor, Company Z. Delivery of antiseptics to the Country A market is carried out by Logistics service provider X and to the Country B market by Norbert. Delivery process includes transportation from Company Y to the central warehouse in Country C and to Company Z's (sub-contractor) warehouse in Country B.

7.3.3 Delivering process

Delivering involves warehousing, handling customer orders, preparing shipment, customer invoicing, shipping the goods to the end-customer and reverse logistics.

7.3.3.1 Warehousing (storage and inventory management)

Stock for the Country A market is stored in the 3PL warehouse in Country C and for the Country B market in Company Z's DC in Country B. Product availability at the warehouses is checked on a weekly basis by the customer service center (CSC).

7.3.3.2 Handling customer orders

CSC handles all customer orders. However, there is no direct customer order for the Country B market, stock is just replenished at Company Z's warehouse.

7.3.3.3 Preparing shipment

CSC organizes shipment of the goods in consultation with the 3PL provider, Logistics service provider X.

7.3.3.4 Customer invoicing

Company Y and the logistics providers invoice the Company X warehouses and then CSC in turn invoices the end-customer. Most of the invoicing is done automatically through the system.

7.3.3.5 Transportation (outbound logistics)

The goods are picked-up at the central 3PL warehouse in Country C and delivered to the end-customers in the Country A market by Logistics service provider X. This process is excluded from the flow for the Country B market since Company Z is responsible for delivering the products and organizing the transportation to the end-customers.

7.3.4 Returning process

CSC handles all product returns. In the case of antiseptics returns are considered as a minor problem and cost for Company X.

7.4 Appendix 4

7.4.1 Summary of Hibi KPIs Table

KPIs	DEFINITION	FREQUENCY	GRANULARITY	WHO REPORTS KPI	SOURCE
OLC	of lines ordered	weekly	per function	SCP team	SAP data
Complaints per million (CPM)	number of total complaints per million pieces sold	monthly	product family level	Quality team	SAP data
Tied-up-capital	operational inventory value in euros and days of sales	weekly	product level	SCP team	SAP data
Backorders	actual BO in value (euros) and number of lines versus target BO value and number of lines	weekly	product level	SCP team	SAP data
Forecast accuracy (BIAS, PLIX)	forecast versus actual sales	monthly, rolling three months average	product level	SCP team	Historical data
BIAS	accuracy of total forecast versus actual sales				
PLIX	accuracy of the product mix				
Supplier pricing deviation	if the supplier is invoicing the company at a different price to what was agreed	monthly	per product, supplier and commodity group	HQ Finance	SAP data
Order line availability					
OLA Warehouse	number of order lines not delivered to end customers due to stock-outs on planned GI dates, not related to warehouse issue	weekly	MRP level	SCP team	daily SAP data
OLA Factory	number of backorder lines not related to a supply issue from the factory	weekly	per factory	SCP team	daily SAP data
Supplier capability (OTIF)	capability of the supplier to deliver "on time and in full"	monthly	per product	Sourcing team	base data from MHC Purchase orders
Plan attainment	actual production output versus planned	monthly	-	Sourcing team	data generated from BCM's own internal manufacturing system
Overall equipment efficiency (OEE)	production line capacity utilization	monthly	-	Sourcing team	data generated from BCM's own internal manufacturing system
Overdue invoices	value of unpaid invoices	monthly	supplier level	Sourcing team	data generated from BCM's finance department
Product manufacturing complaints	number of complaints related to product manufacturing issues	monthly	-	Sourcing team	SAP data -> CAPA form
On-time arrival	on-time arrival of goods at warehouse from factory	monthly	-	Logistics/Transporting team	-
Non-conformity notification (NCN)	number of notifications per supplier	-	supplier level	Logistics/Transporting team	-
NCN Truck	amount of notifications concerning damaged goods, goods not ordered, missing goods, too many/few products and problems with the barcodes				
NCN Receiving	issues of delays, advanced shipping notifications (ASN) not given to Deufol and communication errors				
Damaged goods	% of transport boxes that arrive misshapen at the warehouse	monthly	supplier level	Logistics/Transporting team	-
Product complaints	number of complaints related to any product issue. A product complaint is not necessarily connected to a product default	monthly	product family level	CSC team	SAP data
Service complaints	number of service complaints as % of orders, numbers of service complaints closed down and their closing time	monthly	product family level	CSC team	SAP data
Order to Cash Management (OTC)	number of credit and debit notes as % of orders, number of orders processed and how many times it has been processed until completed	monthly	product family level	CSC team	SAP data
Telephony	number of calls answered, the time it takes to process them and number of abandoned calls	monthly	product family level	CSC team	SAP data
Returns and express deliveries	% of return and express shipments to the customer versus number of normal orders	monthly	product family level	CSC team	SAP data

7.5 Appendix 5

7.5.1 Interview template

- What is Product X supply chain?
- Which are the Product X products? Explain
- What are the main processes in the Product X supply chain? And what the subprocesses/activities?
- Why is Product X supply chain perceived as unstable and unreliable? What are the root problems?
- What challenges are you experiencing in Product X supply chain?
- Do you think the Product X supply chain measurement is done correctly? If not why?
- How do you measure the performance now? Do you use a specific performance measurement framework?
- What metrics/KPIs do you use?
- How is the measurement carried out? What methods/tools do you use?
- How do you collect the data?
- Where do you get the data?
- Who are the key people responsible for Product X measurement and metrics?
- Why haven't the metrics you adopted in the past always been the most suitable ones?
- What metrics do you lack? Do you have suggestions for the areas/activities that should be measured?
- Do you need metrics per function or area?
- You say you lack consistent and sufficient metrics for Product X supply chain. Why is that a problem?
- Do you think the main problem is caused by the lack of using a SPM framework or sth else?
- How do you define the strategy for Product X? To be cost efficient or responsible? What is the most important?

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