MASTER

Strategic supply chain planning in a multi-echelon environment
identification of the CODP location constrained by controllability and service requirements

van Wanrooij, M.R.

Award date:
2012

Eindhoven, August 2012

Strategic supply chain planning in a multi-echelon environment: Identification of the CODP location constrained by controllability and service requirements

by

M.R. van Wanrooij BSc

M.R. van Wanrooij BSc — INPG 2012
Student identity number 0590180

in partial fulfilment of the requirements for the degree of

Master of Science
in Operations Management and Logistics

Public version

University Supervisors:
Prof. dr. A.G. de Kok, TU/e, OPAC
Prof. dr. ir. J.C. Fransoo, TU/e, OPAC

Company Supervisor:
Herr R. Kübler, Hilti A.G., Head of Global Logistics Materials Management

TUE. School of Industrial Engineering.
Series Master Theses Operations Management and Logistics

ARW 2012 OML

Subject headings: CODP, controllability, hybrid MTO/MTS, organizational alignment, product segmentation, Supply Chain Management, strategic supply chain planning, strategic supply chain design.

I. Abstract

Hilti faces high stocks and unreliable service rates especially for SKUs with highly variable demand. To resolve this problem, this thesis proposes a redesign for Hilti's strategic supply chain planning. The demand of SKUs is characterized by probabilistic behavior. If the coefficient of variance of the demand of a SKU at a stock point is higher than 1.33, the stock point cannot be controllable. We state that the supply chain for a SKU cannot be controlled if the CODP is situated at a stock point that has a coefficient of variance that is higher than 1.33, i.e. if the CODP is located in an uncontrollable stock point. If a SKU is highly variable and the promised customer lead times are short, the CODP is likely to be situated in an uncontrollable stock point. In order to regain control of the supply chain, we have made a framework that aids in resituating the CODP (i.e. further upstream). The framework takes the service requirements and controllability of stock points as a starting point for redesigning the CODP location. By simulating the complete supply chain for a number of SKUs we can compare the redesign with the current situation. From the simulation follows that the redesign will lead to controllable stock points and that will also result in significant cost-savings for Hilti.

II. Management summary

Hilti has a large product portfolio with a large variety of properties. Figure II-1 shows that only 7% of the products generated 80% of the turnover in 2011. This means that the other 93% of the products only contribute to 20% of the turnover. These numbers do not have to be problematical and are even typical. However, they do indicate that all SKUs should not be treated in the same way with respect to materials management (Silver et al, 1998). At Hilti there is no policy on *how* products should be treated differently and as a consequence, employees throughout the organization and especially MO managers do not know *how* to differentiate between products.

The lack of a conceptual design that differentiates differences between SKUs, contributes to high inventories at locations where it is not necessary, and also leads to a service rate which fluctuates heavily. In Figure II-2 the frequency of the service rates per SKU are shown. 41% of the SKUs had on average a service rate that was lower than 95%.

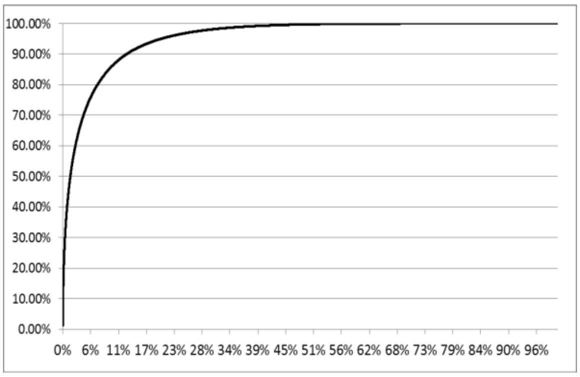


Figure II-1: Relative turnover per SKU in 2011.

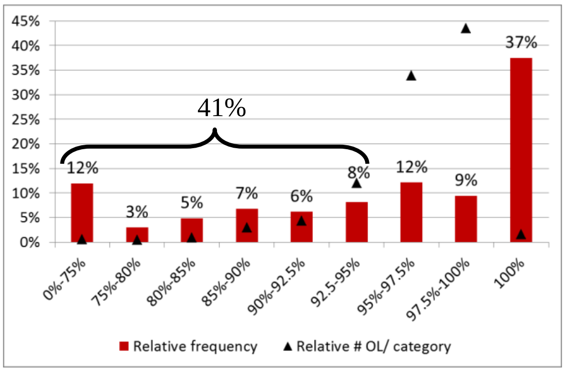


Figure II-2: Histogram of the frequency and relative amount of order lines per service rate interval for CWs and DCs in 2011.

In this thesis we argue that the main cause of these unreliable service rates is the result from poor strategic supply chain planning. One important consideration when designing the strategic supply chain plan is selecting the customer order decoupling point. The Customer Order Decoupling Point (CODP) is that point in the organization where the customer order penetrates. The CODP functions as a buffer, i.e. it protects the upstream part of the chain from demand uncertainty. The buffer for instance protects against delays and consolidation in the production process, so that production constraints (like setup times, utilization and batching) can be respected. If demand uncertainty is not buffered, then production becomes inefficient and uncontrolled, and thereby too costly. Furthermore, the placement of the CODP gives important input for the production and distribution policy: if the CODP lies downstream in the chain, this leads to a Make-to-Stock (MTS) policy, if the CODP lies more upstream, this leads to an Assemble-to-Order (ATO), Make-to-Order (MTO) or Engineer-to-Order (ETO) policy, Figure II-3 depicts this. Whether you have a MTS, ATO, MTO or ETO policy influences the models applied upstream of the CODP and downstream of the CODP. At Hilti, there is no clear decoupling in the supply chain.

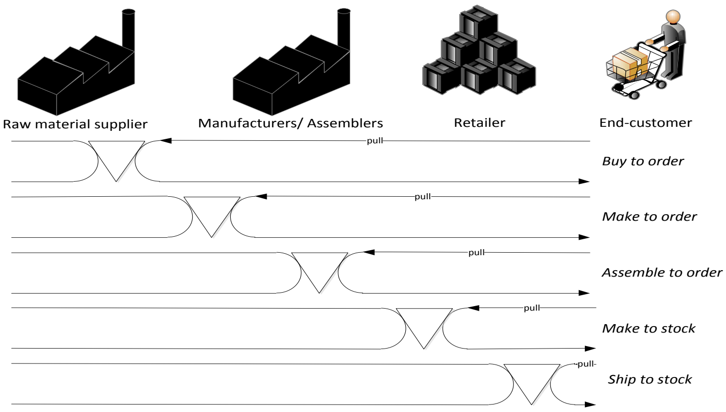


Figure II-3: Supply chain strategies (Naylor et al, 1999).

The other important consideration when designing the strategic supply chain plan is controllability. We define a controlled activity as an activity with which performance is carefully aligned with a predefined target. An activity can only be controlled, if the activity is controllable. If the activity is to determine the proper stock levels (base-stock and safety stock) for a SKU at a stock point, the controllability is dependent on to the probabilistic characteristics of the demand in the stock point. These probabilistic characteristics of the demand are a fact of life: they cannot be changed, unless e.g. a different marketing strategy is applied. Uncontrolled is an (implicit) choice: if the wrong (or even no) process or guidelines are formed to cope with uncontrollability, the supply chain is uncontrolled. Whether stock points are uncontrollable can be measured with the variability of the demand of a SKU in that stock point. Variability is measured by the coefficient of variance (CV). If the CV of the demand in a stock point is higher than 1.33, the stock point is uncontrollable. This uncontrollability is visible in the actual service rate on SKU-level: SKUs either have a service rate that is extraordinarily high (i.e. there's a large days-on-hand value), a service rate that is disappointingly low, or a rate that is approximately at the desired level of service. Currently, the latter is achieved more by coincidence than by good supply chain planning as supply chain planning is unreliable for these types of products as indicated earlier. The fact that Hilti (unconsciously) tries to control uncontrollable stock points is an issue as it either leads to exceedingly high stock levels for SKUs that are rarely sold or to undesirably low service rates for those that generate a high turnover.

The research questions that follow from this diagnosis are as follows.

1. What product segmentation needs to be adopted so that the stock points become controllable and the supply chain is in control? What should be the position of the CODP per product segment to make the current situation controllable?
2. What consequences does the change of the CODP position have for the customer service requirements? And for the costs?
3. What consequences are there for steering strategies after placement of the CODP? I.e. how is the strategic decision of placing the CODP translated into the tactical and operational level?

In this thesis a redesign for the strategic supply chain planning has been made. This redesign takes into account the uncontrollability of stock points and the desired service requirements. Together, these are inputs for finding an appropriate location for the CODP. In general, the candidate-CODPs lie in-between the upper boundary indicated by the service requirements and the lower boundary identified through the CV. If this is not the case, then there is a 'gap' and a different method is needed to decide on the CODP position. For Hilti, the gap occurs for highly volatile products. In other words: the service requirements of delivery within 1 day with a service rate of 97.5%, lead to uncontrollable stock points, because the resulting CODPs have a CV > 1.33 for the highly volatile products.

With the proposed redesign the CODP will be consciously placed, so that Hilti can control their stock points. Table II-1 gives an overview of the product segmentation that we recommend to implement. The amount of products that we expect to be in a category is indicated. It is not possible to deliver all products within one day, because this would mean that uncontrollable stock points have to be controlled. As argued earlier: that is impossible. Therefore, this redesign introduces a product segmentation with the following groups: 'runners', 'steady products' and 'specials'. Only the runners are allowed to be on stock in the HCs. The specials are assembled if they are ordered. In that way, there are benefits of component commonality with other SKUs.

Furthermore, every product family has some products of which the necessity of having them in the product portfolio can be disputed. Clear examples can be found in the tools-area: within one family, products can be assembled with and without TPS (theft-protection system) or with and without PTR (punching through prevention). The existence of two types leads to a higher variability. Typically, one of the two sells significantly more than the other. In such a case, we suggest that one of the two should be removed from the product portfolio.

Segment	CODP	Service requirements Service rate	CLT	Policy	% of total products
Runners	CW/RDC/NDC+DC+HC	No change	No change	MTS	1%
Steady products	HQ WH or CW/RDC/NDC or DC	No change	Extension to: 1-7 days	MTS	12%
Specials	Factory	No change	Extension to: 10-40 days	MTO	87%
Remove	n.a.	n.a.	n.a.	n.a.	unknown

Table II-1: Proposed product segmentation and its strategies.

Based on a simulation of the complete supply chain, we were able to calculate potential cost savings of the product segmentation. There are some differences between how Hilti's supply chain operates and how the tool works. The tool assumes that the supply chain is decoupled and applies the synchronized-base-stock policy. The synchronized-base-stock policy is applied on the component stock of assembly items which leads to savings in the component stock. Therefore, the calculated cost savings include this policy and if this policy is not implemented they will be lower. Furthermore, in the current situation there are no delivery costs if a product is sold in a HC, because the customer collects the product themselves. These costs need to be subtracted from the savings. However, as the simulated savings are so large, we expect that there still will be cost-savings even if the extra parcel deliveries have been taken into account.

Implementing the product segmentation yields a paradigm shift for Hilti. Therefore, it is important that Hilti carefully executes a change management process before Hilti can take action to physically implement the product segmentation.

If the product segmentation, the decoupling principle and the SBS policy are implemented the stock points will become controllable and the service rates become more reliable. In addition there are cost-savings. Because of a decrease in the total stock value, the total annual supply chain cost and the total supply chain investment cost will decrease vastly: respectively with 16.1% and 35.4%.

III. Preface

The last two years as a student of the master's program Operations Management and Logistics have passed quickly. The second year of my masters I have lived abroad, first in Buenos Aires followed by six months in Liechtenstein. I have been able to cope with this thanks to the ongoing support of friends, family and colleagues. I would like to make use of the preface to say a special thanks to some of them.

First of all, I need to thank Ton de Kok for always being there to answer my questions, no matter how busy his schedule was. Despite being on a sabbatical, he chose to keep on supervising me. He even took the effort to 'fly in' for my intermediate presentation. This indicates how committed he is and I appreciate that.

Secondly I would like to thank my supervisor and colleagues at Hilti. Rüdiger Kübler's support and feedback was always constructive and motivating. Ian Hartman always found time to answer my questions. Beyond that, he was also open for brainstorms, thereby giving valuable input for my thesis. The lunch break-discussions on many different topics, but especially those about cultures and politics reloaded the engine for the afternoon. I also owe a thanks to Christian Putzi, for his enthusiasm (among others on alignment and goal-setting) and to Thomas Oertel for sharing the passion for logistics.

Finally I also have to thank my friends and family that were there for me when I needed them, especially those that took the effort to visit me in Liechtenstein. Those weekends were much fun and moreover, gave me a good excuse not to work (I needed that). My parents believe in all the choices that I make and always stand by me. Thank you for the trust and the support. And last but not least, I owe a big thanks to Paul Zuurbier. Although sometimes I was not there for him the last year, he kept on supporting me, and us, with all the patience of the world. I admire how he was always able to show me the positive side.

Merel van Wanrooij

August 2012

IV. Table of Contents

V. Table of Figures

VI. Table of Tables

1 Introduction

Nowadays almost every organization has a sophisticated, automated supply chain planning system. However, one is likely to over-trust such a system and thereby overlook the essential concepts for basic supply chain planning, such as decoupling and controllability.

The concept of decoupling is well-known, but controllability has not been clearly defined before. In this thesis a framework is introduced to assess the controllability of the strategic supply chain design.

At Hilti, the firm at which this research has taken place, all products are treated similarly with respect to supply chain planning. While only a handful of products of Hilti's large portfolio are responsible for a large part of the turnover. This results in an uncontrollable supply chain. In order to regain control the developed framework is applied to Hilti, from which a product-segmentation has been derived that takes the perspective of materials management. Although the segmentation takes the materials management perspective, it also takes into account the marketing, sales and production perspective.

1.1 Company description

Hilti AG, hereafter called Hilti, produces different products for the construction industry, ranging from specialized tools to perishable chemicals to commodity consumables, in total around 63,000 finished products. Hilti makes a distinction between global (FERT) and national (ZFER) products, this number includes both. The products from allied suppliers are included and spare parts are excluded. Hilti does not only manufacture or source these products, but is also responsible for the distribution and sales of these products. This means that Hilti owns the complete supply chain.

The organization was founded in 1941 by Martin Hilti and is still a family owned company. It is operating in more than 120 countries and has approximately 20,000 employees. The organization is characterized by a direct sales model and annual sales are around 4 billion CHF. The brand promise is: "Hilti. Outperform. Outlast" (www.hilti.com). The corporate goal is to "passionately create enthusiastic customers and build a better future". The vision for 2015 is based on four priorities: growth, differentiation, productivity and people. In the direct sales model a customer can reach Hilti in five ways: through Customer Service, E-business, Hilti Centers (HC), Hilti ProShop (shop in shop) and through a sales representative (Van or Territorial Salesman). There are more than 200,000 direct customer contacts on a daily basis. In 2008, the company was hit by the financial crisis and therefore, different cost savings needed to be realized. Although the organization grew in 2011, profits decreased. This implies that there are problems within the organization and by doing a thorough problem analysis of the supply chain we intent to identify the problems related to that.

The customer is important for Hilti: throughout the whole organization customer satisfaction is the most important driver. An example is that the plants have pictures on the performance boards that show the direct consequences for customers based on activities in each plant. With respect to customer service rates, Hilti strives to achieve an average service rate of 97.5% in combination with delivery within 24 hours. However, as this is an average, it is inevitable that some customers will be served as promised while others may be disappointed and have to wait longer. There are no guidelines for Market Organizations (MOs) that either prioritize which products (do not) have to be delivered within the 24h delivery window or which customers those products need to be delivered to within that time frame.

This project has been commissioned by the Global Materials Management (GLM) department. At Hilti, materials management includes demand management and inventory management. In this chapter, a short introduction to Hilti's supply chain is given by discussing the primary processes, the organization and planning and the control processes (Bemelmans, 1986). Based on these descriptions a problem definition can be formulated.

1.1.1 The Global Materials Management organization

The organization chart of global logistics is depicted in Appendix A- Figure 1. GLM is one of the four global functions in global logistics and it has overlap with the Global Manufacturing and the Product Management organization. In GLM there are several challenges that can be recognized with respect to decision authority.

The first issue is that there are two leaders for a regional material manager. Appendix A- Figure 1 shows that the responsibilities for Global Logistics Materials Management include those of local materials management. However, the local materials managers report directly to the Logistics region manager. The dotted line indicates that local managers also report to GLM.

The second challenge is that not only the type of products varies widely, but also the demand characteristics per stock keeping unit (SKU) differ largely. Therefore the materials management approach cannot be painted with the same brush for every SKU. Although differences can be found in the control processes of different tiers, these are not directly driven by the differences in the primary processes and the differences in the control processes.

1.1.2 Hilti's supply chain

A general overview of Hilti's supply chain is given in Figure 1-1. This figure provides an overview of the complete supply chain, from supplier to customer. The number of locations involved per tier is indicated between brackets. The suppliers, factories, warehouses (WHs) and distribution centers (DCs) are spread all over the world. The lead times vary strongly due to the geographical foot print. Most of the turnover is generated in Europe and also the majority of the factories (5 out of 8) and the majority of the head quarter warehouses (3 out of 4) can be found here.

All the material flows from the factories until the end-customer are part of the distribution network. In Figure 1-1 a simplified overview of this network is given. If the stream of goods between a factory or an allied supplier and a regional distribution center (RDC) or a national distribution center (NDC) or a central warehouse (CW) is large enough, then the goods will be transported directly to this RDC/ NDC/ CW. The difference between the RDC/CW and the NDC is that the NDC generally serves as an extra tier in the supply chain. For example North-America has a NDC: goods are shipped from Europe/China/Mexico to the NDC and then shipped to a DC. While in most European situations there is a direct delivery from HAG to the RDC/CW. The difference between a RDC and a CW is that a CW only serves the country where it is located while a RDC also serves other countries in the region. The small streams of goods between the factory/ allied supplier and the RDC/ NDC/ CW are consolidated in a head quarter warehouse (HQ WH).

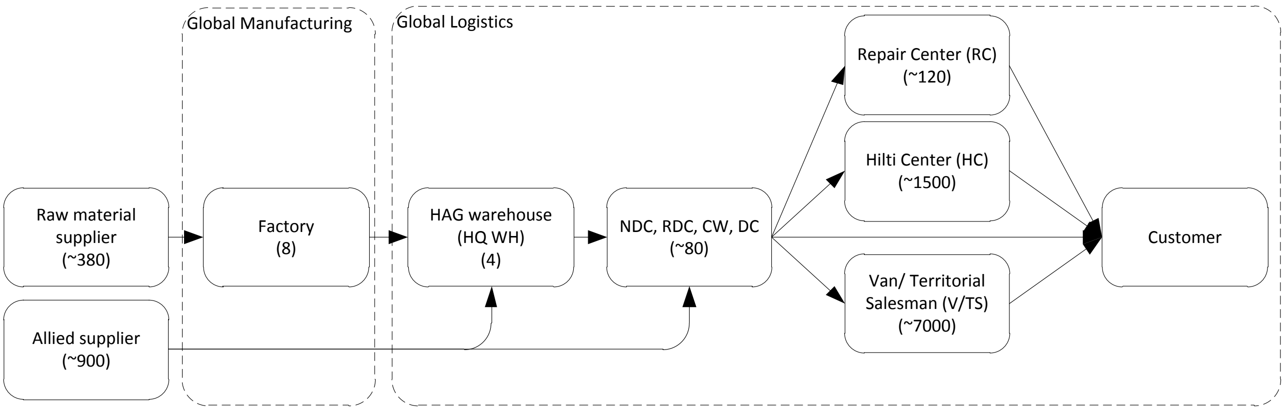


Figure 1-1: Hilti's supply chain (simplified).

The distribution network is similar for all SKUs. The only difference that could occur for products that flow through this part of the organization is their availability and their customer lead times. Currently, Hilti only makes a distinction between the different sales channels for a product's required customer lead time and availability. The HCs can be compared to a retail store: 85% of the customer order lines should be available at the moment that the customer is in the shop. What type of products is held on stock in the shop is decided per Market Organization (MO) and therefore differs per MO.

An MO typically encompasses a country or a larger region. The orders placed through the other sales channels *should* be delivered not later than the next day and the availability requirement is 97.5%. This means that currently, Hilti has two different customer lead time and availability requirements that depend on the sales channel. *Should* as this is what Hilti is aiming for. However, if a customer for instance orders through the e-business, it can choose whether it wants to be delivered tomorrow or later. The customer is compensated by Hilti if it requests for a later delivery as it does not have to make the promised lead time.

Hilti's controls the complete supply chain which makes it possible to optimize the stock division from a multi-echelon perspective. This is unique given that usually the retail and manufacturing part are represented by two organizations.

1.1.3 Hilti's planning and control processes

Previously Hilti's material flow has been described. However, to coordinate a supply chain two flows are required: the materials flow and the related information flow. The planning and control of a supply chain ensures that the right material and resources are available at the right location and on the right time. Hence, this material flow cannot be coordinated without communication and thus information flows through the organization. The information flow at Hilti is briefly described in this section. Next, with the help of a generic MRP II hierarchy, we elaborate on the planning and control process.

Information flow

The information flow at Hilti is depicted in Appendix A- Figure 3. The boxes indicate roles. The arrows indicate the direction of the information flow and the dotted rectangles indicate the means of communication that can be used to exchange information. We would like to refer to the research proposal (van Wanrooij, 2012) for a detailed description of the information flow. For now, it is sufficient to say that the MO material manager is in contact with all tiers of the supply chain (through the global export and the BU material manager). This may be an indication of a lack of decoupling in the supply chain. We will elaborate on this concept in the next two chapters.

MRP II hierarchy

The planning and control process for plants and warehouses is based on MRP II. In Appendix A- Figure 2 a standard overview of a MRP II hierarchy is given. On a process level, Hilti works in a similar way. The largest differences between Hilti and organizations in general, are found in the frequency and the level of detail on which Hilti works with respect to long-term planning.

Hilti has two information systems working together, this is depicted in Appendix A- Figure 4. One is an advanced planning and scheduling system (APS) called SAP-APO, and the other one is the execution system, SAP-R/3. Every weekend, APO makes a long-term plan per item for the upcoming 18 months. The frequency of the long-term forecast is higher than usual: in most organizations this forecast is conducted 2 to 4 times a year, with a horizon around 6 months to 5 years. Moreover, usually the long-term forecast is made on a level as high as possible. For Hilti this could be the total volume of a Business Unit or maybe in some cases on product family level. The current long horizon forecast per individual item leads to an unrealistic plan, because it is too detailed (Hopp & Spearman, 2008).

Next to long-term forecasting and planning, APO runs every night to make a short-term plan for the upcoming 12 weeks; this planning is based on item forecasts which are entered by the MOs, the current stock and safety stock and the outbound and inbound orders. This information is send daily to the different factories and distribution centers so that they can make their tactical and operational planning decisions.

1.2 Project description

The previous section introduces GLM at Hilti, its primary processes, the organization and the planning and control processes. Several things stand out: the long-term forecast frequency is high, the long-term forecasts are probably too detailed, the information flow hints at a lack of decoupling and the service requirements are not based on the product (demand) characteristics, but on the sales channel.

Of the above described issues, decoupling and the service requirements are worth diving deeper into, as both are part of strategic supply chain planning. As will be discussed in the next chapter, strategic supply chain planning consists of defining a customer order decoupling point (CODP) per SKU. For now it is sufficient to state that the location of this CODP is dependent on the service requirements and the controllability of stock points. Chapter 2 gives more insight in how these concepts are related. Strategic supply chain planning is essential for tactical and operational supply chain planning. The plan resulting from the strategic level serves as input for planning on the tactical and operational level.

The purpose of this project then is to show that the current supply chain is uncontrolled and uncontrollable and that a redesign of strategic supply chain planning can make the supply chain controlled again. The project provides Hilti with a redesign that supports in strategic supply chain planning. Furthermore, it should deliver a product segmentation from which rules and guidelines can be derived for the tactical and operational level.

1.3 Report outline

The research conducted follows the methodology of the regulative cycle (Aken, Berends, & Bij, 2007). First, explorative analysis is used to define a problem. Next to that, a theoretical basis is created that supports in analyzing, diagnosing and designing a solution for the problem. Then, the redesign is tested and the results of the redesign are validated. Thereafter, the implementation plan for the redesign can be made.

This methodology is also visible in the structure of this report. Figure 1-2 gives an overview. In this chapter the problem has been defined based on an analysis of the primary processes at Hilti. Thereafter, chapter 2 gives a theoretical background to analyze and diagnose the problem in chapter 3, and to redesign the strategic supply chain planning in chapter 4. This redesign is tested by means of a simulation and chapter 5 gives the experimental design for this simulation. The results and validation for this redesign are given in chapter 6. Thereafter, chapter 7 describes which aspects are important for the implementation of the redesign. We conclude this thesis in chapter 8, with general conclusions about the designed framework and with recommendations for Hilti.

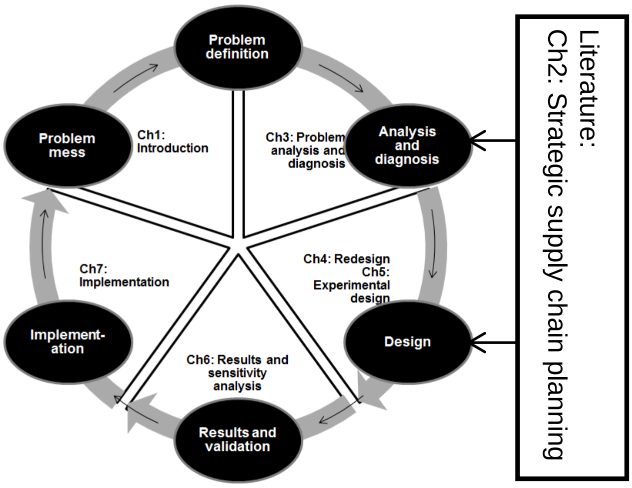


Figure 1-2: Report outline based on the regulative cycle.

2 Strategic supply chain planning

In the previous chapter an introduction to Hilti's supply chain has been given. We have indicated that our main concern with respect to the current supply chain is that no distinction is made between based on product characteristics and that no clear decoupling takes place. If the strategic plan is not clear or if it is wrongly defined, the input for the tactical and operational level is incorrect. As the alignment of these hierarchical levels, as well as the alignment between different departments, is important in order to avoid local optimization, this is an important issue.

In this chapter, the position of strategic supply chain planning in organizational alignment will be discussed. Based on this discussion we can elaborate on decoupling the supply chain: the decoupling concept is explained and the connection to strategic supply chain planning is made. Thereafter, the concept controllability is introduced. Next, the connection between decoupling and controllability is made by answering the following question: where should the supply chain be decoupled so that the supply chain is under control?

2.1 Strategic supply chain planning and organizational alignment

Strategic supply chain planning is an important part of organizational alignment. Organizational alignment is the encouragement of integration between internal supply chain functions (Aschenbaum, et al, 2009). In this chapter, we will focus on describing successful alignment and the role of strategic supply chain planning within this alignment.

Alignment contains horizontal and vertical aspects. The vertical aspect includes alignment of the strategy, the tactical and the operational level. The horizontal aspect includes alignment between different departments and functions. Furthermore, there are different viewpoints from which successful alignment can be described. The different viewpoints do not exclude each other; on the contrary, they could complement each other. In order to explain the different viewpoints and their coherence, Figure 2-1 is used. The complexity of horizontal alignment grows by moving top-down through the organization. In Figure 2-1, this increase is visualized in a triangle-shape.

The first research viewpoint that can be distinguished is Human Performance Management (HPM). The second research viewpoint is analytical: the alignment of metrics. We will elaborate on this topic in the remainder of this chapter. We do not elaborate on HPM alignment in this section, since that the redesign made for Hilti is solely addressing the metrics alignment. However, in chapter 7 the implementation of the redesign is discussed and here the HPM alignment is also important. Therefore, a short the elaboration on the HPM viewpoint can be found in chapter 7.

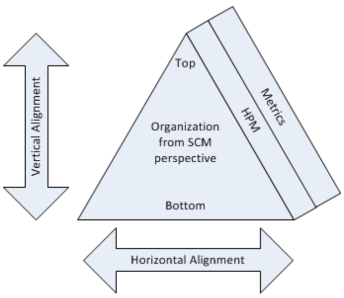


Figure 2-1: Connection of different viewpoints on alignment from a SCM perspective.

2.2 Customer Order Decoupling Point

A supply chain is characterized by the flow of materials and the flow of information. The decision on how materials and information flow through the organization is made on the strategic level. Next, these requirements and the design are translated into the tactical level. This tactical level controls and coordinates the operational level. Therefore, in order to characterize a supply chain, a difference is made between the strategic, the tactical and the operational level. Figure 2-2 gives an overview of the separate control levels and their relations.

Before we explain the different levels and their relations, we explain the concepts that are represented in Figure 2-2. For our explanation, we follow the concepts and frameworks by Bertrand et al (1998). We start by defining the decoupling points (DPs). There are four main reasons to decouple according to Fransoo (2010, p. 6): "(1) non-synchronized processes between successive steps (speed, setup, uncertainty); (2) differences in opportunities to vary resources; (3) differences in commonality and (4) differences in available information".

The occurrence of each reason should be checked for all processes in the supply chain. Based on this the DPs can be specified. Subsequently we can delineate the production units (PUs). PUs are modules in a larger system and are structurally independent of one another, but work together to achieve the overall requirements. PUs should be as independent as possible: a PU should be able to realize its work without information on the previous or subsequent PU (Fransoo, 2010).

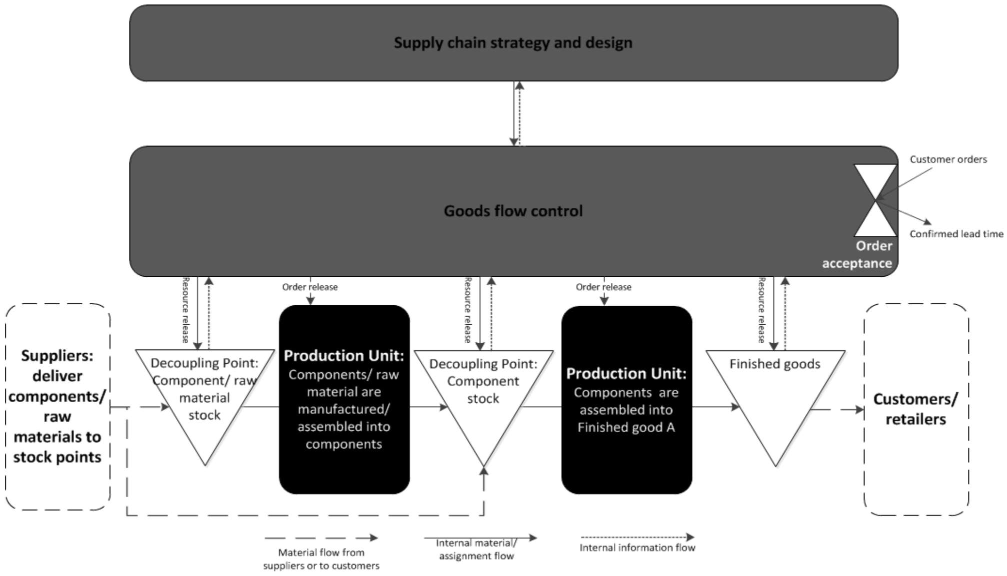


Figure 2-2: Different control levels within an organization's supply chain (Fransoo & Kok, (2003), Bertrand et al, (1998)).

Each level can be typified by constraints based on: the previous level, the main issues, the decision support material and the decision frequency ((de Kok, 2011), (Ivanov, 2010)). In the remainder of this section, we will discuss these characteristics per level.

2.2.1 Supply chain strategy and design (Strategic level)

The strategic level is characterized by the definition of the service requirements and the supply chain design. Sometimes, these two characteristics are dealt with separately. In that case, the strategic level includes the service requirements and the design level determines how these service requirements can be met, from a high-level perspective.

In general, the main issues on this level are the service requirements, the product portfolio, the product technologies, the process technologies and the geographical footprint. The decisions on these main issues are supported by risk and cost-benefit analyses. Whenever a new product or product family is introduced, supply chain design decisions should be taken, which result in the supply chain strategy for a product (family). Naylor et al, (1999) state that there are five different supply chain strategies, which are represented in Figure 2-3. First, the figure and the represented strategies are briefly explained. Next, we substantiate on which strategy or strategies we focus in this research.

The overview depicted in Figure 2-3 distinguishes between four types of organizations: 1) the raw material supplier, 2) the manufacturer, 3) the assembler, and 4) the retailer. The four types of organization do not have to be four different organizations. One could think of different combinations, but often, subsequent types can be found in one company, such as direct sales of a manufacturer or assembler to a customer, without the interference of a retailer.

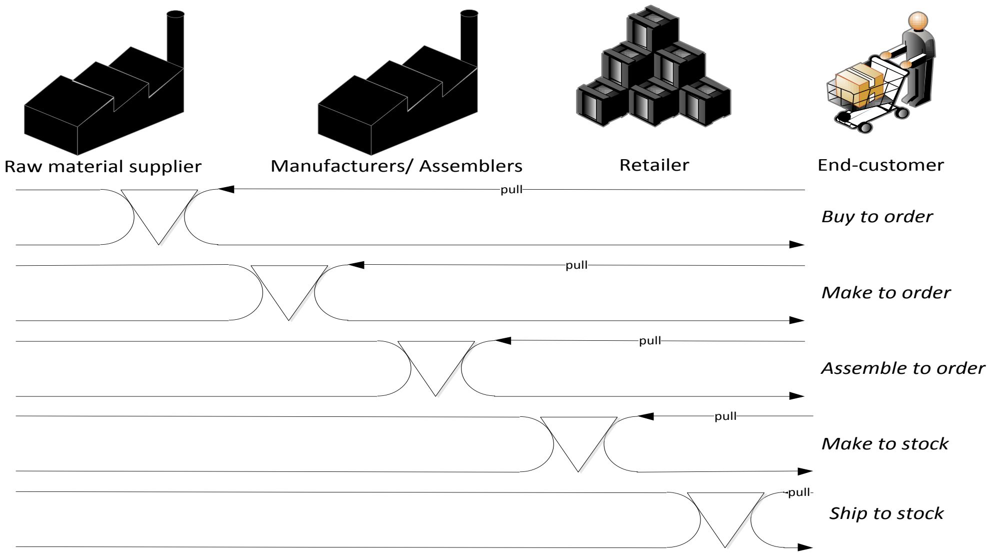


Figure 2-3: Supply chain strategies (Naylor et al, 1999).

The five strategies can be explained by the placement of the customer order decoupling point (CODP) in the supply chain. Upstream of this decoupling point the products are either pushed (through forecast) or pulled (through replenishment) and downstream the decoupling point the products are pulled by the end-user. If we compare Figure 2-2 and Figure 2-3, we see that each DP in a supply chain can take the role of CODP.

If the chain has a buy-to-order (BTO) structure, this means that after the placement of an order by a customer, the organization purchases the materials needed to fulfill this order. This is common for unique products. A make-to-order (MTO) structure indicates that the manufacturing process is not started until the customer places an order. This strategy is used in organizations that manufacture many different products from the same raw materials. In the assemble-to-order (ATO) structure, the CODP lies between the manufacturing and assembling process, so that the final assembly follows upon a customer order. A make-to-stock (MTS) structure is often applied in an organization with standard products that have demand spread out over different locations but with a low variation. The last structure, ship-to-stock (STS), only differs from make-to-stock in one aspect: the demand should be at fixed locations. Many manufacturing organizations do not use one single strategy, but a combination of two or more strategies because their product portfolio varies strongly. We elaborate on one of those strategies: hybrid MTO/MTS.

Hybrid MTO/MTS

A pure MTO strategy is typically followed when the products are more expensive and customer specified, thereby there is a high variety in products ((Soman, van Donk, & Gaalman, 2004), (Kalantari, Rabbani, & Ebadian, 2011)). Moreover, no inventory is kept and production is only started when there is an order. Hence, this is a pull strategy with low storage costs and no forecast dependency (Kaminsky & Kaya, 2009), (Kalantari, Rabbani, & Ebadian, 2011), (Soman, van Donk, & Gaalman, 2004)). Operational issues are order acceptance/ rejection and meeting due dates (Soman, van Donk, & Gaalman, 2004). The production planning is order focused and the competitive priority is to serve customers with a short and reliable lead time ((Kaminsky & Kaya, 2009), (Soman, van Donk, & Gaalman, 2004)). So, this strategy is lead time focused.

A MTS policy is applied when there is a low variety in products and products are less expensive ((Kalantari, Rabbani, & Ebadian, 2011),(Soman, van Donk, & Gaalman, 2004)). Inventory is held at the end of the supply chain, preferably close to clients and the demand is estimated based on forecasts ((Adan & van der Wal, 1998), (Kaminsky & Kaya, 2009)). Typically, the relative inventory costs are high (Kalantari, Rabbani, & Ebadian, 2011). Therefore, inventory planning is an important operational issue. Also lot size determination and demand forecasting are operational issues. The competitiveness depends on the fill rate (Soman, van Donk, & Gaalman, 2004). This strategy is inventory focused.

The combination of these strategies brings some complexity with respect to capacity allocation, capacity planning and operational scheduling and control decisions. Important issues marked in literature are the allocation of resources and capacity, the operational scheduling and control decisions, the order acceptance/rejection decision and the decision of which product should be MTO and which should be MTS. In order to find a suitable policy for this environment, a balance is to be found for buffering, the stock levels and the order uncertainty (Soman, van Donk, & Gaalman, 2004). In order to find this balance, numerous variables and interests of different functions and departments need to be aligned.

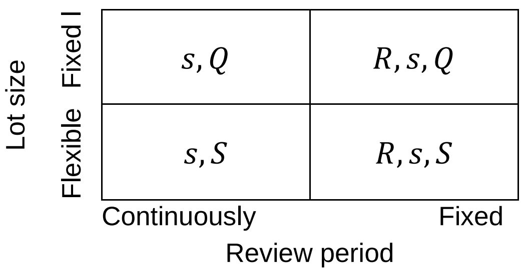
The purchasing function aims on clear communication with the supplier about when and within what timeframe supplies are expected. Due to a combined MTO/ MTS environment, on the one hand there is a steady demand for the material needed for the MTS products, but a large variation on demand for MTO products. This has impact on the relation with the supplier and therefore, the purchasing function would like to know early which products to order and with what priority. So, the communication between the purchase function and the supply planning deserves attention.

Next, the supply planning department needs to plan the resource and capacity allocation and needs to create a production scheme. Therefore, information is needed on the required inventory planning for the MTS products and information about the orders and released due dates for the MTO products. The inventory planning depends on the forecasts made by demand planning, as well as the order release for MTO products. There might be a conflict of interest between the supply and demand planning department, because the supply planning department strives for an optimal use of available capacity while the demand planning department aspires demand satisfaction. Although it seems logical that each department strives for their goals, this could lead to sub-optimization. This recognition requires alignment between the departments.

Third, the relation between the sales and marketing function and the demand planning department might be under pressure. Besides the well-known issue around customer satisfaction (the sales and marketing function strives for a 100% satisfaction while this is not achievable from a logistics/ mathematical perspective), also the customer lead time might be under pressure for MTO products, due to production of MTS products.

2.2.2 Goods flow control (Tactical level)

The tactical level is concerned with the means by which the strategic objectives can be realized and therefore, translates the strategic goals into complementary goals and objectives for each function in order to provide balance to the supply chain. (Corbijn et al, 2011). I.e. the tactical level is responsible for coordinating and controlling the supply chain. The constraints from the strategic level are the design (i.e.: BTO, MTO, ATO, MTS and/or STS), the product portfolio, the product technology, the process technology and the geographical footprint. The main issue on the tactical level is the service level agreement (SLA) with customers, suppliers and internal production units (PUs) (de Kok, 2011).



Where:
$s \coloneqq reorder\ point$
$Q \coloneqq lot\ size$
$S \coloneqq order - up - to - level$
$R \coloneqq review\ period\ in\ number\ of\ periods$

Figure 2-4: Replenishment strategies.

In order to decide on SLAs, a scenario analysis can be made. In this analysis certain lead times, lead time reliability, lot sizes and safety stocks are varied. This analysis is only made if there is an impulse from the strategic level or if SLAs need to be adjusted. Through this control and coordination the supply chain strategy is translated into the operational level. This coordination and control is not only a matter of doing calculations, it also involves alignment in communication. Different models that operate on the left-side of the decoupling point are the replenishment strategies in Figure 2-4, or push strategies such as KanBan and forecasting.

2.2.3 Operational level

The operational level focuses on executing the goals which are set on the tactical level. In SCM this is concerned with supply chain operations planning (SCOP) and Sales and Operations Planning (S&OP) (de Kok, 2011). The constraints from the tactical level are planned lead times, lot sizes, safety stocks and capacity. Main issues that arise are the sales plan, the capacity plan, the release of materials and the release of resources. The support for the decision on the main issues can come from different information systems, such as APS and MRP, or from pull mechanisms, such as KanBan, or even from an excel sheet. Which mechanism is used is decided on the tactical level, the options are shortly addressed in chapter 3.4. The decision frequency in operational planning can vary from monthly (S&OP) to daily (SCOP). Whenever a decision is taken on the operational level, communication with the various PUs, departments and functions is necessary.

2.2.4 Relation with alignment

Alignment between the functions and departments is important, in order to maximize profit or minimize costs. Without alignment several difficulties may arise between the different functions and departments due to conflicts of interest. Through horizontal alignment these problems can be tackled. In Figure 2-5 the two functions with which the logistics function has direct contact are shown.

The relation between the logistics function and the purchasing function can be described as follows. A two-way relationship exists: on the one hand a material flow from the purchasing towards logistics takes place; on the other hand there is an information flow from logistics to purchasing (Naylor et al, 1999). It is important that the logistics function feeds the purchasing function with information on what materials are needed with what time frame. Additionally, the purchasing function needs to give information on expected delivery (times) of materials. Issues might arise when there is a lack of communication or a conflict of interest between these two functions.

The logistics function and sales and marketing function also have a two-way relationship, which can be described by a materials flow from logistics towards sales and marketing and reverse an information flow (Naylor et al, 1999). An example of a conflict of interest between these two functions is the desire of the sales and marketing function to have a 100% customer satisfaction, while from a logistics perspective it is impossible to have a 100% customer satisfaction, for instance due to variation in demand.

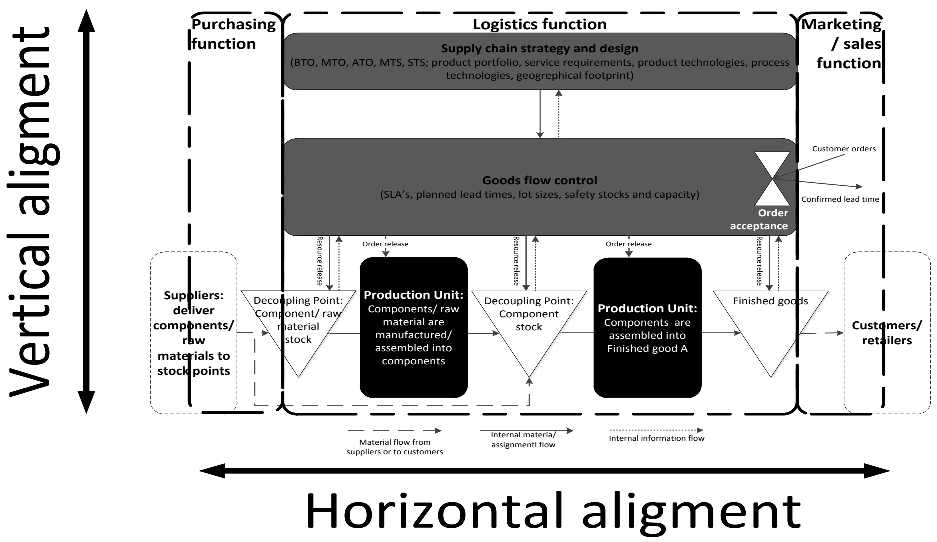


Figure 2-5: Connection between different control levels and organizational alignment.

2.3 Controllability[1]

We discussed in the previous section that although marketing and sales would prefer a 100% customer satisfaction, this is impossible to guarantee due to the probabilistic behavior of demand. In this section we elaborate on the consequences of probabilistic behavior in terms of controllability of stock points and capacity.

Under the assumption that the demand of an item triggers all activities in the supply chain, the variability of demand for materials and resources can be derived from the variability of the demand of end-products. Generally, to control a stock point the safety stock and base stock level for an item need to be defined. Most methods to define these stock levels are dependent on, among others, the expected standard deviation and the expected demand of an item. If the volatility of a stock point is high, methods to calculate these stock levels become unreliable and moreover, generate stock levels that are too high on average but still too low to satisfy demand peaks. In that case, we speak of uncontrollability. A similar line of thought can be applied to the demand for resources. We would like to point out the difference between the two concepts 'uncontrollability' and 'uncontrolled'. Uncontrollability is a fact of life: due to the probabilistic characteristics of the demand the stock point and/or the resources *cannot* be controlled. Controlled activity is an activity with which performance is carefully aligned with a predefined target. Uncontrolled is an (implicit) choice that applies on the supply chain as a whole: if the wrong (or even no) process or guidelines are formed to cope with uncontrollability, the supply chain is uncontrolled.

Now we can give a formal definition of controllability. We define an arbitrary performance indicator X(t) measured at time t. We measure X(t) during the time interval (t,t+Δ). Then we define controllability of X(t) with respect to the time interval (t,t+Δ) as:

$X(t)$ is (α, ε)-controllable if a target value x* exists for which we have that

$$P\{\Delta^{-1} \int_t^{t+\Delta} X(t)dt \in \left((1-\alpha)x^*, (1+\alpha)x^*\right\} \geq 1-\varepsilon \qquad [1]$$

Informally, the target value x* should be achieved with sufficiently high probability. Of course, this probability depends on the particular control rules used. Now the following can be observed:

If the demand for a material or resource has a variability such that the standard deviation of the demand noise exceeds a threshold value times the expected demand and the availability of the material or resource cannot be increased or decreased within a pre-specified time frame, then it is impossible to achieve any target value of any performance indicator related to the material or resource with acceptable high probability.

Implicitly is assumed that the performance indicator used is directly or indirectly related to the extent that we can synchronize the availability (supply) of a material or resource and its demand. Through this observation and by deriving the variability of the material or resource demand from end-product demand variability, an objective way of measuring the controllability of processes and materials in the supply chain is found.

If the probability density function that describes the noise is based on historical demand data, the coefficient of variation of demand is the major cause for lack of controllability. Aside from stating that the CV is an indicator of controllability, it would be good to additionally identify a threshold value for the CV that indicates that a stock point becomes uncontrollable. The CV is used more often to indicate volatility, but it has not been related to the controllability of stock points yet. There is no clear indication in literature about an exact maximum value; in fact the mentioned maximum ranges from 1 to 2. Where these values come from however, is unclear. In this thesis we choose a value in between these borders (without a clear argumentation as well) that is used in the manufacturing context (for resource demand): 1.33 (Hopp & Spearman, 2008). The squared coefficient of variance simply is the coefficient of variance to the power of two. In the remainder of this thesis the squared coefficient of variance (SCV) and the coefficient of variance (CV) are used interchangeably.

---

[1] The theory in this section is to a large extent developed by Prof. dr. A.G. de Kok, but has not been published.

If the variability of a product is high, the downstream stock points of a supply chain become uncontrollable. Uncontrollability is visible in the actual service rate on SKU-level: SKUs either have a service level that is extraordinarily high (i.e. there's a large days-on-hand value), a service level that is disappointingly low, or a level that is approximately at the desired level of service. The latter is achieved more by coincidence than by good supply chain planning as supply chain planning is unreliable for this type of products as indicated earlier. The fact that uncontrollable stock points are tried to be controlled is a problem: this either leads to exceedingly high stock levels for SKUs that are barely sold or to undesired service rates.

We are not only interested in defining whether a process or stock point is controllable or not, but also we would like to indicate how a process can be made controlled if it is not. The amount of noise should be reduced to make a stock point controllable again; there are two principle ways of doing that:

1. Aggregation of demand
2. Postponement of the need for information about the demand

The aggregation of demand or postponement of the need for information about the demand can be achieved by moving the CODP upstream or by SKU management (i.e. remove SKUs from the product portfolio or consolidate multiple SKUs into one SKU). We can summarize this in a quadrant as depicted in Figure 2-6. The quadrant is based on (Fisher, 1997); he makes a distinction between innovative and functional products and states that innovative products require a responsive supply chain whereas innovative products require an efficient supply chain. Instead, we are more particular with respect to controllability by making a distinction based on the customer demand variability. We elaborate on *how* to and in *which* situations to apply these two methods in the next section.

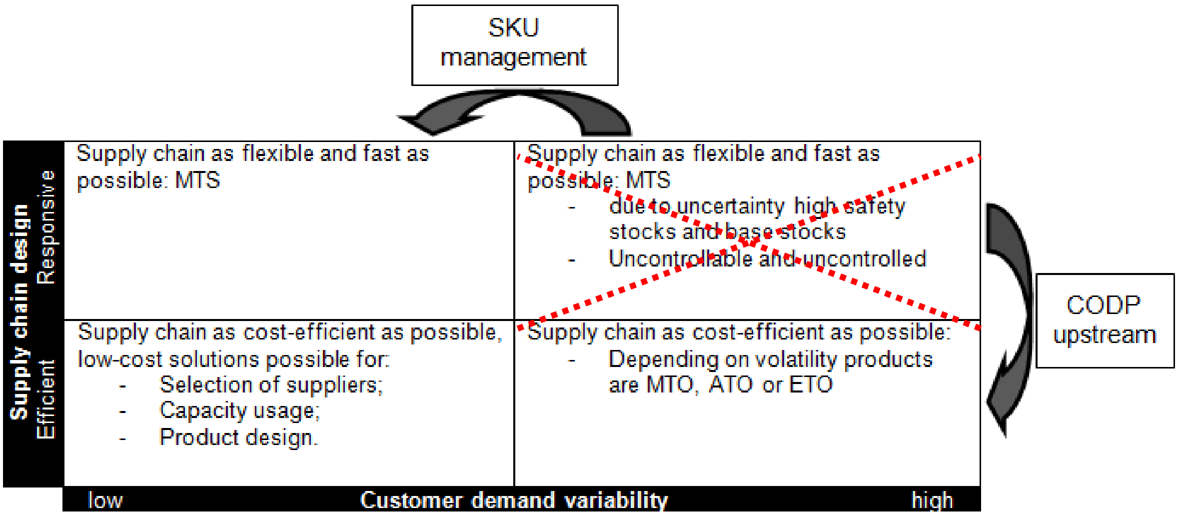


Figure 2-6: Model for choosing right supply chain for a product, based on controllability.

2.4 The role of the CODP in controllability

As previously discussed, four levels of supply chain modeling can be distinghuished:1) supply chain strategy, 2) supply chain design, 3) supply chain planning and 4) supply chain operations. These four levels are reciprocal, which indicates that each level should not work in isolation (Zhao et al, 2011). For each level a model should be chosen, so that it complies with the previous level. The supply chain strategy results in requirements, such as delivery performance and customer lead time, but also controllability should be a requirement. Then, these goals are input for the supply chain design. A manner to design a supply chain can be the placement of a CODP. The input of a subsequent level is always given by the output of the previous level. By obeying the rule that the output for each level is the input for the next level, the modeling of the supply chain is aligned.

This sounds simple, but in reality there are different decisions to be taken per level, which are based on the input and that create the output. If one of the four levels is operating autonomous, without using the correct output or input, or without knowing what types of decisions should be made, then the metrics are not aligned. This can have severe effects on the complete supply chain, like a bullwhip.

In Appendix B- Figure 5 an overview is given of decisions that need to be made per level, the input data, and the output data per level, based on Ivanov (2010). Needed input data for the design stage is, among others: product variety, SKUs, BOM, demand and time-to-market. The output of the design level is inter alia how to deal with the demand uncertainty. In this section a framework is introduced that aids in decision making during the design stage, so that based on the input data, the correct required output data is formed. This framework focuses on the CODP location because this is exactly the decision that needs to be made on the design level.

Different products can have different CODPs, depending on their properties (Bertrand et al (1998)). Determining these CODPs however, has received limited attention in academic writings.

In literature the position of the CODP is said to be primarily dependent on the service requirements (Bertrand et al (1998); Ashayeri and Selen (2005); Skipworth and Harrison (2006)). However, based on the controllability discussion in the previous section, we can state that not only the service requirements but also the demand volatility should be input for the CODP location. We introduce a framework that aids in determining whether the current CODP position is the correct one, based on both the demand volatility and the service requirements.

Based on the previous two sections and Appendix B- Figure 5, the framework that is depicted in Figure 2-7 is created. The framework can be divided into four stages: the item selection, the data, the processing of the data and the final decision on the CODP position. Each stage is explained more thoroughly in the following subsections.

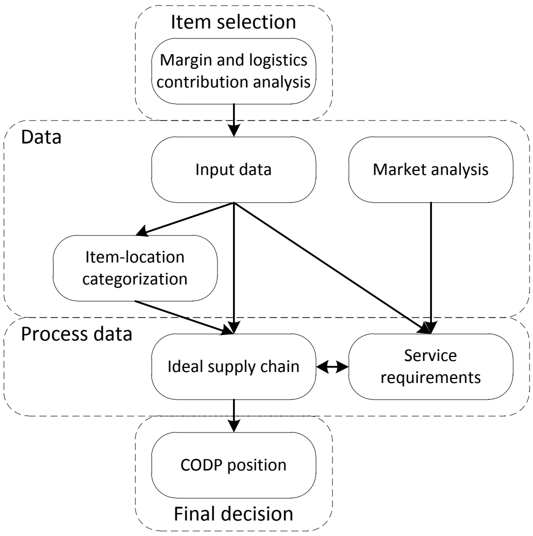


Figure 2-7: Framework for positioning the CODP.

2.4.1 Item selection stage

The ideal situation would be to analyse for all products whether the CODP currently is located in the best position. However, this takes time and based on efficiency considerations we would like to select products for which this analysis has the most impact (Ashayeri and Selen, 2005). Therefore, we start with a margin and supply chain cost contribution analysis. Positioning the CODP will have an impact if the logistic costs have a large impact on the profitability of a product. Formula [2] and [3] indicate the rates on which we base our qualification.

$$P_{ti} = \frac{s_{ti} - c_{ti}}{s_{ti}} \qquad [2]$$

Where:
$s_{ti} := total\ sales of\ item\ i\ \ for\ period\ t\ in\ CHF$
$c_{ti} := total\ costs\ of\ item\ i\ for\ period\ t\ in\ CHF$

$P_{ti} :=$ *rate of profitability of item i for period t*

$$SC_{ti} = \frac{sc_{ti}}{s_{ti}} \quad [3]$$

Where:

$s_{ti} :=$ *total salesof item i for period t in CHF*

$sc_{ti} :=$ *total supply chain costs of item i for period t in CHF*

$SC_{ti} :=$ *rate of total supply chain costs of item i for period t as a % of the total sales*

Our first priority is to target products with low profitability ($P_{ti} < 0.5$) and relatively high supply chain costs ($SC_{ti} > 0.1$). The reasoning behind this decision is that if a substantial amount of the profitability is lost due to the supply chain costs, it is likely that we can decrease the SC_{ti} by (re)placing the COPD, i.e. placing it more upstream.

2.4.2 The data stage

The next stage is to acquire input data on the selected items. We need this data for the subsequent stages. First, we will discuss which input data is needed and next, we explain how this input data is used for deciding on the DPs.

Skipworth and Harrison (2006) state that product demand information, product design information, capacity information and throughput efficiency information are needed to properly place the CODP. According to Ashayeri and Selen (2005) capacity constraints should also be taken into consideration. An overview of the necessary input data per item is given in Appendix B- Table 1.

Long lead times especially occur if the item is manufactured in one continent and sold in another. Therefore, different transport times between similar nodes are present and accordingly different CODPs for each item-location combination are possible. In section 2.3 it was already indicated that the squared coefficient of variance (SCV) is an indicator for controllability of a stock point. Therefore, it is important to identify the item-location combinations that deliver directly to end-customers: for each of these points the squared coefficient of variance (SCV) should be calculated. The volatility measure is important input for the ideal supply chain. The 'item-location combination' step supports in defining the level of analysis from this point further. Therefore, item-location combinations need to be identified before moving to the next stage.

The final piece of input data needed is a market analysis in order to discover whether the service requirement customer lead time can be changed (i.e. extended). For this analysis coordination with the marketing and sales departments are necessary.

2.4.3 The data-processing stage

The 'ideal supply chain' can be made, based on the service requirements, the item-location combination and the input data. For drawing the ideal supply chain, we follow the concepts and framework of Bertrand et al (1998), which was discussed in section 2.2.

In order to map the supply chain, several decisions need to be made. As discussed in section 2.2 first the DPs and PUs need to be identified. Subsequently, two other types of input are especially important for deciding on the CODP-location. The first type is the service requirements and the second one is the volatility of the demand. On the one hand the volatility defines the lower boundary for the candidate CODPs, this statement is based on the controllability of stock points. On the other hand the service requirements define the upper boundary for the candidate CODPs. We will explain this reciprocity in more detail, by carefully defining both types of input and relating them to the above statements.

Service requirements are customer-oriented functional requirements. These requirements need to comply with the strategy of an organization. Typical service requirements can be defined in terms of delivery performance and customer lead time. Recall that all the DPs in the supply chain are a candidate-CODP and that the lead times between all DPs are known. The service requirement 'customer lead time' gives us a time frame within which the delivery per item should be realized. Likewise, the service requirement 'delivery performance' indicates with which certainty the customer delivery per item should be realized. Together, the time-frame and delivery performance requirement can be matched in order to indicate the upstream-border of the CODP-location: the CODP cannot be more upstream because otherwise the delivery within the time-frame subject to the delivery performance requirement cannot be *assured*.

As stated in section 2.3, we the SCV of a stock point that serves as CODP, should not be higher than 1.77 ($= (1.33)^2$). As the demand of different stock points can be aggregated by moving upstream in the supply chain, the SCV is per definition smaller upstream than downstream. If a DP has a coefficient of variance that is higher than the specified maximum, this DP cannot be a CODP candidate. Consequently, the SCVs of the more upstream DPs are calculated, until a SCV smaller than 1.77 is found. This means that the volatility of the demand at a DP indicates the most downstream CODP candidate.

A problem arises though, if the upstream boundary is in a lower tier than the downstream boundary. This could mean that the organization wants to promise shorter customer lead time than that is logistically possible (due to the volatility constraint). A different perspective is that the item has an uncommonly high volatility due to sporadic demand or through (sporadically occurring) peaks in the demand. In the latter case it could be that there is no lower limit for the CODP, because in no stock point a SCV smaller than 1.77 can be found. These two different causes should also be addressed differently. The first cause, an unrealistic customer lead time, is one that can be changed by the organization, based on e.g. a market analysis. The volatility is a characteristic of the customer demand and changing this characteristic is not a straightforward decision that can be made by a company. The measures an organization can take to vastly lower the volatility are of a different nature: for instance postponing the production step where this item starts to be different from other items. Numerous solutions can be thought of, but the decision which solution to select is organization-specific.

We conclude from the data processing stage that candidate-CODPs lie in between the upper boundary derived from the service requirements and lower boundary based on the volatility of an item in a DP. The service requirements should be derived from the organization's strategy. Market analysis can give insight on the flexibility of these requirements. Furthermore, it might be possible that the upper boundary is in a lower tier than the lower boundary. How this problem should be dealt with is company specific and therefore not addressed in this section.

2.4.4 Final decision stage: deciding on the CODP position

As elaborated on in the previous section, the candidate CODPs for a SKU lie normally speaking in between the upper boundary indicated by the service requirements and the lower boundary identified through the SCV. The costs of the different CODP locations per SKU can be calculated, allowing the organization to consciously decide which CODP suits them best. However, if there are no candidate-CODPs (as described previously), then a different method is needed to decide on the CODP position. In Figure 2-8 an iterative process indicates a manner to address this problem on SKU level.

First, an organization needs to check whether the SKU is superfluous. This can be done by evaluating the product family on cannibalism and checking whether for instance postponement management could be applied. If the product is not candidate for removal, information on the current CODP, the service requirements and the end-customer demand is needed in order to decide whether the SCV is too high. Next, the organization needs to decide whether it prefers to keep the CODP in an uncontrollable stock point for strategic reasons. If this is not the case, the CODP has to move upstream. But how far exactly, depends on the costs-to-serve trade-off of which the result and order in which it is conducted is company-specific; examples are (1) whether the customer is willing to wait the extended lead time versus the supply chain costs of keeping the CODP downstream and (2) the costs of expedited freight and fast delivery versus economy freight and slow delivery. These trade-offs extend beyond the supply chain department and therefore, should be agreed with by all stakeholders. The new proposed CODP location iterates to the decision '$c^2 > 1.77$?'. This iteration takes place until a proper CODP for the SKU has been found.

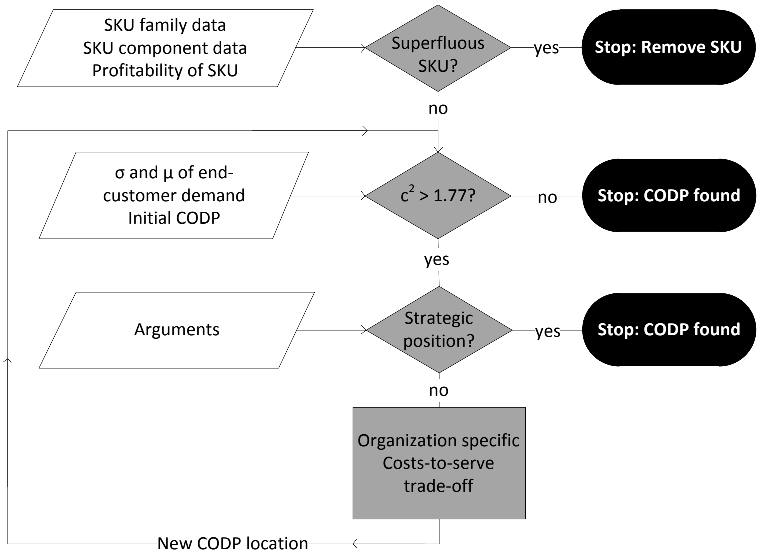


Figure 2-8: Generic decision tree for application in case of a 'hole' between upper and lower bound of candidate-CODPs.

Figure 2-8 can be directly related to Figure 2-6: if there are no candidate-CODPs, the SKU is located in the upper-right corner of Figure 2-6. In order to tackle this problem Figure 2-6 suggests to either move the CODP upstream or to execute SKU management. The decision tree of Figure 2-8 tells step by step what to do if the CODP is located at an uncontrollable stock point.

2.5 Conclusion

In this chapter three main concepts were introduced: decoupling, controllability and the role of the CODP in controllability.

We have defined decoupling and argued its importance in successful metrics alignment, both horizontally and vertically. The success of metrics alignment is dependent on how the goals as described in the strategy are translated into models on a design, planning and operations level. Furthermore, the concept controllability is introduced. We state that a point in a supply chain, either a resource or a stock point, can be uncontrollable. This uncontrollability is a consequence of demand variability. If an organization does not realize that the supply chain contains uncontrollable points, the supply chain is uncontrolled. In order to solve this matter, two methods are suggested: moving the CODP upstream and SKU management.

The CODP framework aids in determining the best CODP location based on the service requirements such as customer lead time and based on the controllability measure 'coefficient of variance'. We have indicated that sometimes it can be problematic to use this framework if the upper boundary (based on the service requirements) is in a lower tier than the lower boundary (based on the coefficient of variance). We have developed a generic decision tree to cope with this situation.

Based on these three concepts Hilti's supply chain can be analyzed. If we conclude that the current design is uncontrolled and contains uncontrollable elements, a redesign based on the introduced CODP framework can be made.

3 Problem analysis and diagnosis

Chapter 1 described the as-is situation at Hilti from a GLM perspective. Several notable points have been pointed out, such as the long-term forecast frequency, the level of detail of a long-term forecast, the lack of decoupling and that the service requirements are not based on the product (demand) characteristics, but on the sales channel.

Hilti has a large product portfolio with a large variety of properties. Figure 3-1 shows that only 7% of the products generated 80% of the turnover in 2011. This means that the other 93% of the products only contribute to 20% of the turnover. These numbers do not have to be problematical and are even typical. However, it does indicate that not all SKUs can be treated in the same way with respect to materials management (Silver et al, 1998). However, Hilti does not have any rules on *how* the products should be treated different. As a consequence, employees throughout the organization and especially MO managers do not know *how* to differentiate between products.

Therefore, this analysis focuses on discovering what the different product characteristics are based on the two concepts introduced in the previous chapter: decoupling and controllability. Firstly, the different product characteristics are explored in section 3.1. For this analysis, categorization methods that are already used at Hilti have been used. Next, it is shown that due to the high demand variability in many products, the service levels differ greatly on item level. Thereafter, the average stock levels of the SKUs are analyzed in order to identify a relation between the stock levels and the controllability of stock points. We conclude this chapter by making a problem diagnosis based on the analysis of Hilti data in combination with the theory discussed in the previous chapter.

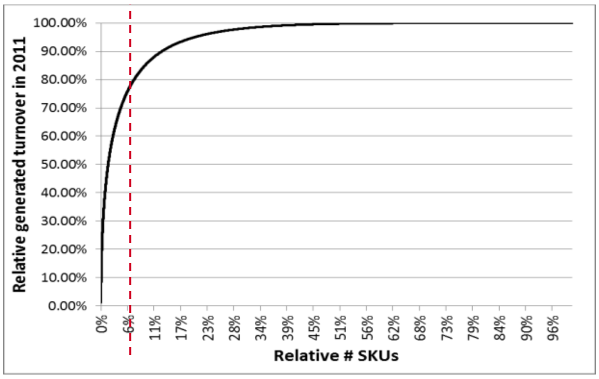


Figure 3-1: Relative turnover per item in 2011, FERT products.

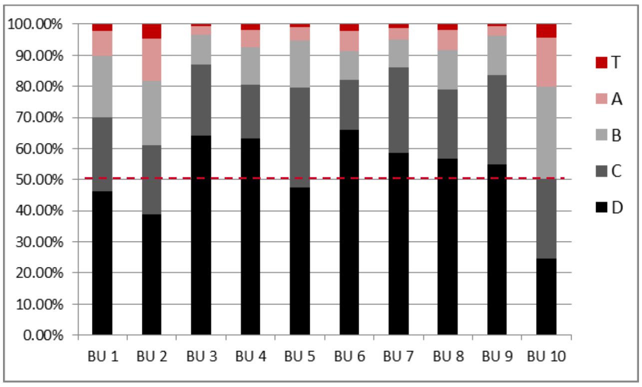


Figure 3-2: TABCD categorization per BU.

3.1 Product characteristics

At Hilti three "categorization methods" are used to express properties of end-items at global level. As a result, information about end-items based on these categorizations can be extracted relatively easy. The extracted data provides more insight in the differences between the products on BU level. Before the results per BU for each categorization is shown, each method is briefly explained. We would like to emphasize that although categorization method 2 and 3 did exist, GLM previously did not actively use them.

Generated turnover: This method classifies the end-items based on their contribution to the total turnover. First, the end-items are sorted in decreasing order, based on their turnover. Then the relative contribution per end-item is calculated and cumulated. Based on this sum, the following categories are distinguished:

T: 50% of total turnover
A: 30% of total turnover
B: 15% of total turnover
C: 4% of total turnover
D: 1% of total turnover

Order frequency: The order frequency measures the number of order lines per 26 weeks on global level, in Appendix C- Figure 6 is shown how the global data is extracted from the data available in the BI. One order line can contain more than one amount of the same product. Three categories can be distinguished:

Q: $\# \, order \, lines \; > 30$

R: $6 < \# \, order \, lines \leq 30$

S: $\# \, order \, lines \; \leq 6$

Order variability: In order to classify the items based on the order variability, the coefficient of variation is measured. The coefficient of variation (CV) is defined as the standard deviation divided by the average demand, based on the global weekly demand over a period of 26 weeks.

$CV = \frac{\sigma}{\mu} = \sqrt{\frac{\sum_t (x_t - \mu)^2}{n-1}} / \mu$; where x_t is the amount of orders at time t (in days or weeks).

The following classes are distinguished:

U: $CV \leq 0.5$

V: $0.5 < CV \leq 1$

W: $CV > 1$

In Figure 3-2, the relative amount of products per generated turnover category per BU is shown. For each BU it is visualized what percentage of the products is marked as category T to D. Basically, a similar pattern is visible that could be recognized without a distinction between BUs: each BU has around 7% of the products in category T and A. Moreover, for six out of the ten BUs more than 50% of their products only represent 1% (D) of the total turnover (indicated by the red dotted line in the figure). Low contribution to the total turnover implies that there is not much sales. The other two categorization methods give insight in whether the first cause is the case for Hilti.

One reason for generating a low turnover per SKU may be found in the order frequency. Figure 3-3 shows that for most BUs there are in between 20% and 40% products that have a low order frequency, except the BU 7 in which over 80% of the products have a low order frequency.

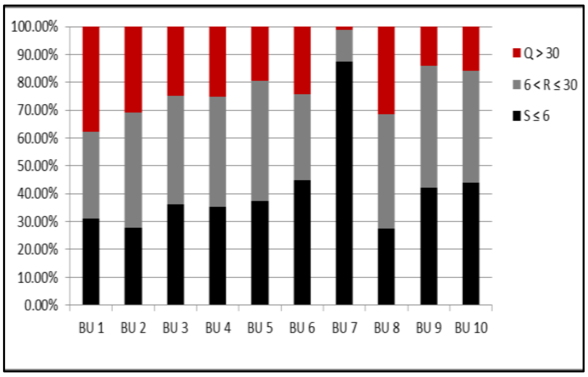


Figure 3-3: Order frequency per BU.

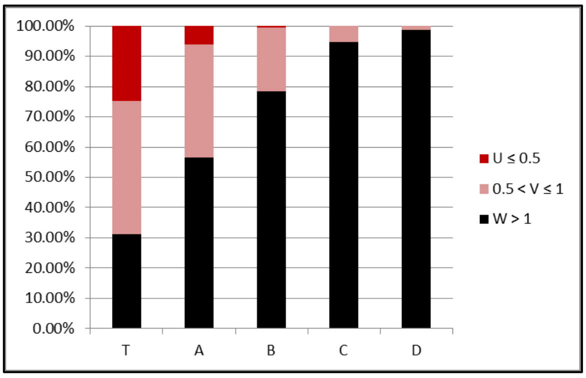


Figure 3-4: Order variability per generated turnover category.

However, the fact that a SKU is not sold frequently does not mean that not many products have been sold: i.e. one order line can represent 10, 100 or even a 1,000 units that are ordered at once. The third categorization method measures the ratio between the standard deviation and the average demand. To calculate the standard deviation, not only the order frequency is taken into account, but also the amount of products per order line. Therefore, we can state that the second categorization method is a special case of the third: the order variability method indicates whether there is variability and the order frequency method can indicate a cause of this variability. Another cause of variability though, can be large differences between the different order lines, independently of how many order lines there are.

In chapter 2 we argued that due to a high variability, stock points become uncontrollable. In Figure 3-4 an overview of the variability per generated turnover category is shown: 40% of the SKUs in category T have a variability higher than 1. Based on this fact we can state that at least 40% of the T products have an unreliable service level. Yet especially for these products, we would expect that the organization prefers to have a reliable service. We will further investigate signs of uncontrollability at Hilti in the next section.

3.2 Customer service

At Hilti, customer lead times and customer service levels do not differ per product, but per sales channel. A customer that buys a product 'from the shelf' at a Hilti Centre (HC) should get that product immediately, just like in a home-improvement store, with an availability of 85%. When a customer orders on the internet or through the customer service center, the lead time is 1 day, with a promised availability of 97.5%.

The only (accepted) differences in service are those due to geographical reasons: i.e. a remote area has a longer customer lead time than other areas. This means that Hilti in general promises at most a 1 day lead time in combination with a service level of 97.5% independent of the product's volatility. If a product has a high volatility on a global level, the volatility on local levels will even be higher. In order to be able to deliver a product within 1 day, it has to be on stock in CWs and HCs. As discussed in the previous chapter, high variance leads to relatively high stock levels in order to cover the uncertainty of the demand. If an organization is not aware of this uncontrollability, an uncontrolled supply chain can be the result.

An indicator of uncontrollability is the service level per item for a fixed period of time. SKUs with highly variable service levels either have a service level that is extraordinarily high (i.e. there's more than one year stock on hand), a service level that is disappointingly low, or a level that is approximately at the desired level of service. The latter is achieved more by coincidence than by good supply chain planning as supply chain planning is unreliable for this type of products as indicated earlier.

Hilti is aware that the current service level is defined as an average per plant (i.e. distribution center or factory). Hilti accepts the fact that the service level for some products is higher than for others, but Hilti does not provide guidelines to decide on this matter and moreover is not aware of the scale of differences between the service rates. In this subsection, it is shown that the current situation is not under control. Firstly, the manner in which the current service rate is measured is explained. Next, we show that the actual service rates from 2011 differed strongly, followed by a specification of the variability and the generated turnover category of the actual service rates in 2011.

Hilti measures its performance regarding customer service with Available to Standard (ATS). ATS measures the percentage of sales order lines that are available when the customer requests them. As described above, this target is set to 97.5% for all stock points that deliver directly to the customer, except for the Hilti Centers. Since the ATS measures whether an order line can be delivered from stock, this performance measure can be compared to the ready rate: the fraction of time during which the net stock is positive. Currently, Hilti measures performance on plant-level: the average service level is calculated for all items together per plant. The plant service level is calculated as follows:

$$\boldsymbol{Plant\ service\ level} = \sum\nolimits_{\forall i} \boldsymbol{ATS\ f_{OL}} / \sum\nolimits_{\forall i} \boldsymbol{OL_i} \qquad [4]$$

Where:
$i = item\ sold\ from\ the\ plant\ to\ the\ end\ customer$
$ATS\ f_{OL} = 1\ if\ an\ order\ line\ cannot\ be\ delivered\ from\ stock\ (failure)$
$OL_i = the\ number\ of\ order\ lines\ per\ item$

Equation [4] shows that products that are characterized by a high service level average out against those with a low service level. Moreover, the more order lines per product with a high service level, the heavier the product will weigh in the average. This means that customers for some items may experience a high service while customers for other items may experience a low service. This does not reflect the service that Hilti wants to give to customers: all customers are to be treated equally, independently of the size and the products that they buy.

Figure 3-5 shows that our expectation of the service on SKU level is met: 41% of the products that were sold in 2011 had a service level lower than 95%. Moreover, from the histogram it can be read that 37% of the products have a service rate that is 100% and that their relative number of order lines is around 1% of the total order lines. This means that these items are probably sold very sporadic but do have a high service. This implies that the stock levels of these items are set in such a way that there is always enough stock to fulfill customer demand. If the item only has 1 to 5 order lines per year, the stock levels are probably at least 260 days on hand (stock for the yearly demand). Although the actual stock level for such a product can be low, due to economies of scale the total stock for these products is high.

However, Hilti desires to have at least a high service for the products in the categories T to B, since these contribute largely to the turnover. Moreover, we have indicated that variability can be an important cause of uncontrollability. Therefore, we zoom in on the service rate differences between high and low variable products and between products that have a large and a small contribution to the turnover.

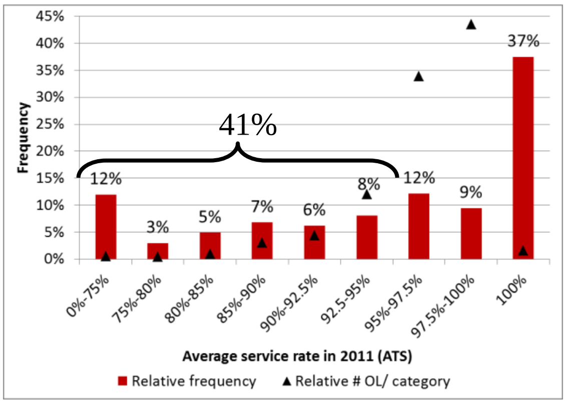


Figure 3-5: Histogram of the frequency and relative amount of order lines per service rate interval for CWs and DCs in 2011.

An overview of the service level per variability category is given in Figure 3-6. There is an extra category, labeled "-". For these SKUs the CV has not been calculated, because in the time-frame (26 weeks) taken for calculation, there were no order lines and this results in a calculation error ($CV = \sigma/\mu$; μ is 0 in these cases, therefore there is a division by 0). Yet all items in the database for this thesis were sold in 2011. If the variability has not been calculated for an item in that database, we can conclude that the item was sold in 2011 but not in the time-frame used for the variability calculation. This means that these items are very slow-moving and highly variable. Since these are exactly the items we are interested in, they are included in this histogram.

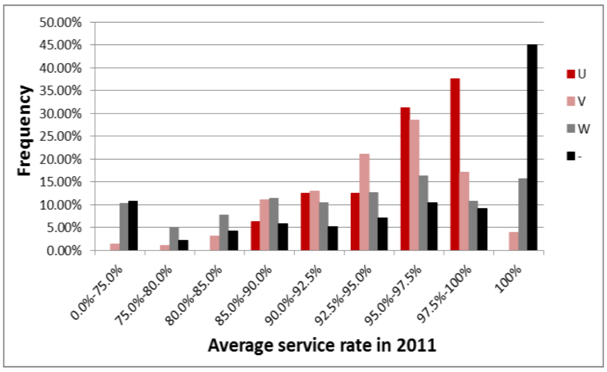


Figure 3-6: Histogram of the frequency per variability category per service rate interval for CWs and DCs in 2011.

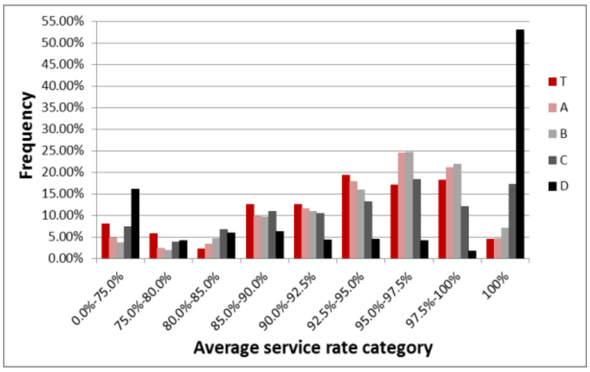


Figure 3-7: Histogram of the frequency per generated turnover category per service rate interval for CWs and DCs in 2011.

In Figure 3-6, the difference between high and low variable items is clearly shown in the way that we would expect it: 45% of the SKUs with very high variability (indicated by "-") have a service rate of 100%. The products with low variability have a more reliable service rate: 68% of these SKUs have a service between 95% and 100%, still 5% of these SKUs have a service rate between 85% and 90%. As argued before, this variation in service rate frequency is an indication of an uncontrolled supply chain and of uncontrollability

Furthermore, as indicated in the previous section, 40% of the SKUs in category T are highly variable. A similar histogram as in Figure 3-6, but then for the TABCD categories, should therefore show that even T products have a scattered service rate. The histogram in Figure 3-7 depicts that indeed 15% of these products have a service rate lower than 85%, this is undesirable for Hilti.

3.3 Stock levels

In Figure 3-8 the turnover per product, the amount of products in the portfolio, and the yearly average stock per product are plotted. This graph clearly shows that the overall stock of products that contribute heavily to the total turnover is much lower than the overall stock of products that contribute little to the total turnover. In fact the products that contribute to the bottom 5% of the turnover represent 60% of the stock.

[redacted]

Figure 3-8: A comparison of the turnover per product and inventory per product in 2011.

Sales Net Stock Value Number of items

This is in line with the expectations expressed in the previous two sections: due to the high volatility especially of the products that generate low turnover, the stock levels of these products are high and the stock points are uncontrollable. Therefore, we would like to make guidelines in this thesis that indicate what the service requirements should be for different product segments.

3.4 Problem diagnosis

In Chapter 3 theory is introduced that has been used in this chapter to analyze Hilti's current situation with respect to controlling the supply chain. We have shown that the service rates among products differ largely. Especially the results that have shown the distinct behavior of highly variable versus low-variable products confirms that the supply chain currently is uncontrolled. This leads to high stock levels of particularly the highly variable products.

Hilti has many different end-products and the production processes differ extensively depending on the product type and business unit. Therefore, the placing of the CODP cannot be painted with the same brush for every product. Aside from the fact that Hilti currently does not consciously place the CODP, Hilti does not decouple in general. As discussed in chapter 2, the placement of the CODP is an important part of the strategic supply chain planning. The location of the CODP has consequences for the production process: the CODP can function as a buffer, i.e. is protected from demand uncertainty. This takes the form of delays and consolidation, so that production constraints like setup times, utilization and batching are respected. If demand uncertainty is not buffered, then production becomes inefficient and uncontrolled, and thereby too costly.

Furthermore, the placement of the CODP gives important input for the policy: if the CODP lies downstream in the chain, this leads to a Make-to-Stock policy, if the CODP lies more upstream, this leads to an Assemble-to-Order, Make-to-Order or Engineer-to-Order policy. Whether you have a MTS, ATO, MTO or ETO policy influences the models applied upstream of the CODP and downstream of the CODP.

We have discussed that the location of the CODP can differ per product (segment). Once the CODP is determined, there are still different ways to comply with these strategies. Imagine that for certain end-items we place the CODP at the Logistic Center Nendeln (LCN; this is one of the HQ WH). In this case, the LCN needs to be replenished by the plants. But, what replenishment model should be used? This decision needs to be taken on tactical level and the right decision can only be taken if the input from the strategic level is adequate. Profound argumentation for the best option can be given based on knowledge of these models and the knowledge of the relevant primary processes.

Moreover, Hilti's supply chain is not always designed to business needs. This means that currently, the supply chain is designed only from one viewpoint: the end-customer. In this document we do not want to argue the importance of the end-customer, but we do challenge that the current service requirements are representing the customer needs. "The customer is always right" is a misconception that may lead to profit erosion and thereby to discontinuation of business. For example Apple built its profitability on technology push and a very limited product portfolio and Nike supplies its products with a six months lead time to the trade. In both cases these policies are based on a careful, but possibly implicit, trade-off between customer service (in its broadest sense) and profitability. We will illustrate this for Hilti by an example: If an item can only be ordered at Hilti, because it is a very specific item, and if this item has an extremely high volatility (i.e. it is ordered rarely), should Hilti then promise a customer lead time of 1 day? The business need of making profit and having controllable stock points seems unconsciously out of scope for Hilti, because the organization deliberately chooses a 1 day delivery requirement, also for these product types.

To conclude this topic: the way in which the supply chain is designed now (excluding the geographical design) only takes into account the customer needs. This has consequences for the costs and for the controllability of the supply chain. The costs that need to be made in order to meet these requirements have not been mapped. Therefore, the supply chain is not always designed to business needs. Apparently, there has been no need so far to design the supply chain in such a way that not only the customer is satisfied, but also costs are taken into account. Moreover, the supply chain is not controlled, and is uncontrollable if the design is not changed.

Research questions

The following questions can be logically formulated based on the problem diagnosis in the previous section:

1. What product segmentation needs to be adopted so that the stock points become controllable and the supply chain is in control? What should be the position of the CODP per product segment to make the current situation controllable?
2. What consequences does the change of the CODP position have for the customer service requirements? And for the costs?
3. What consequences are there for steering strategies after placement of the CODP? I.e. how is the strategic decision of placing the CODP translated into the tactical and operational level?

3.5 Conclusion

In this chapter we addressed the problems found at Hilti in the supply chain and narrowed them down to one source-problem: at Hilti all the products are treated the same from a customer service requirements perspective. This results in uncontrollable stock points for the products that are exceedingly volatile. The application of the CODP theory and the CODP-framework can help in defining a controllable situation. This leads to the following project goal:

Redesign the strategic supply chain planning according to the CODP-theory, so that Hilti can be in control of their supply chain. Show how the service requirements should change by applying the CODP-framework. And show what the costs of current service requirements are in comparison to the redesign. Derive a product-segmentation from the redesign and describe how this change on a strategic level will impact the tactical and operational level.

4 Redesign for Hilti

In chapter 2.4 a framework is introduced to identify the CODP location on SKU level. The framework consists of four stages: item selection, data, process data and the final decision. In general, the candidate-CODPs lie in between the upper boundary indicated by the service requirements and the lower boundary identified through the SCV. If this is not the case, then a different method is needed to decide on the CODP position. The main part of this method is company specific. For Hilti, the gap occurs for highly volatile products. Therefore, stage 4 is adjusted to Hilti's needs.

Three modifications to the generic framework have to be made, in order to make it applicable. Ideally, item selection for analysis should be identified based on the expected impact per item. Unfortunately, the item selection method described in the general framework cannot be applied at Hilti due to data constraints. In section 4.1 an alternative method for selecting items at Hilti is presented. Secondly, the analysis is carried out at item level and the SKUs analysed represent only a small portion of Hilti's complete portfolio. Therefore, it is unrealistic that modifications to the CODP placement for these items would ever create a scenario of constrained capacity. Consequently, capacity constraints have been excluded from the list of input data. In section 2.4.3 we have indicated that a problem arises when the CODP-candidate upper bound is lower than the CODP-candidate lower bound. Addressing this problem has been stated to be organization-specific. Therefore, section 4.2 elaborates on this for Hilti.

4.1 Item selection stage for Hilti

We cannot select the products according to the method defined in our CODP framework, because Hilti currently has no full visibility on the costs per item throughout the complete supply chain. Therefore, we choose a different approach for selecting items. We make use of the existing categorization methods at Hilti to identify items that will benefit from moving the CODP upstream. Furthermore, a scope is identified that is such that the results can be generalized throughout Hilti.

4.1.1 Scope

The above research questions cannot be answered for all products at Hilti within the time-frame available. Instead, a selection that represents (an important part of) the problem needs to be chosen. The item selection method cannot be applied because the data needed to calculate the margin and logistics costs contribution is not easily available. Therefore, a different approach for selecting items is chosen. First, the criteria for identifying our scope are stated. Thereafter, these criteria are applied and lead to a set of items.

The scope is set such that we expect to be able to generalize the results for Hilti. The tooling developed for the scope can be used by for all Hilti products and therefore the application of the redesign will be easier and faster. Our criteria for the scope are as follows:

Hilti has ten Business Units (BUs) and each BU has different characteristics in terms of manufacturing and sales. Therefore, first, a selection is made in terms of BUs. Since data of the complete supply chain is needed, also a selection in factories is made. A BU can contain many different types of products and large BUs have more differences within the product portfolio than small BUs. Therefore, the largest BUs in terms of number of items and relative sales are the most important ones. Next to different BUs, Hilti has eight factories spread globally that all manufacture different types of products. The data collection stage requires input data that is not directly available from BI or SAP. Therefore, the communication with the factories involved is important. In order to simplify this communication, a limited amount of factories should be selected. We prefer these factories to be spatial proximate, so that close communication can take place.

In Appendix D- Figure 7, the relative number of items per BU is given: the BUs 8, 3 and 1 together are responsible for 64% of the products. In Appendix D- Figure 8, we see the relative turnover per BU. The BU 8 clearly represent the largest part, though the BU 1 and BU 4 also have a relatively large contribution to the total turnover.

Besides selecting products per BU, it is possible to select products for the project scope based on the factories where the products are produced. Hilti has eight factories spread globally, of which five are located in Europe. For communication reasons, we prefer to include European plants in the project. Furthermore, the fewer factories are included, the less communication lines there will be. Table 4-1 shows an overview of which plants manufacture for which BUs.

Plant nr	**Country code**	**BU 1**		**BU 2**		**BU 3**		**BU 4**		**BU 5**		**BU 6**		**BU 7**		**BU 8**		**BU 9**		**BU 10**	
		S	E	S	E	S	E	S	E	S	E	S	E	S	E	S	E	S	E	S	E
1	FL		x			x	x*	x													
4	AT					x	x*	x	x					x	x	x	x	x	x		
6	DE		x		x	x					x			x		x		x			
9	DE	x	x	x		x		x	x			x		x		x		x			
18	HU		x													x					
10	MX		x																		
8	CN		x						x								x				
88	CN							x	x							x	x	x	x		
Allied supply											x+		x								x

* **{confidential}**

\+ **{confidential}**

Table 4-1: Products that are manufactured per factory, indicated per business unit.

Based on the defined criteria, we conclude that plant 4 is the best candidate to include in our research. This plant is in Europe, in the Rhine Valley, and the end-assembly of most tools of the large BUs is done here. Therefore, this plant, and consequently all the BUs of which the end-assembly is done in this plant, are selected.

A better insight in the characteristics of this plant can be provided with the help of the material and capacity complexity matrix (Bertrand et al, 1998). Capacity complexity is the complexity of capacity planning, which is a result of the amount of different products that a factory produces, the different capacity loadings per product, the routings per product and the demand frequency of a product. The capacity complexity is high if: a plant produces many different products, the capacity loadings vary strongly per product, the routings vary strongly per product, and the demand frequency is low. The material complexity is based on the unique amount of materials that is necessary to release a production order and the production structures. Together, the material and capacity complexity form a matrix from which control structures can be derived. In Figure 4-1 the matrix with factory 4 mapped in it is depicted.

Factory 4 produces sub-assemblies and assemblies for five BUs: the produced sub-assemblies are partly used in the end-assemblies in this plant and partly in other plants. Furthermore, sub-assemblies from other plants and suppliers are needed for the end-assembly. In the plant a distinction in planning and control is made between the end-assembly and the sub-assemblies. Therefore, the two parts of the plant are described separately.

For all end-assemblies the number of unique materials needed is low, because an end-assembly is not the tool, but the toolbox. The BOM however, can have up to 9 levels. The materials necessary to release a production order include at least two BOM levels, because both assembling the tool and composing the toolbox are done on one assembly line. Therefore, the material complexity is moderate. The demand frequency varies strongly for the end-assemblies. Typically, the products in BU 7 have a low demand frequency whereas the products in the BUs 4, 9 and 8 have a moderate demand frequency. There are around ten assembly lines and per line different product groups can be assembled. Each product group has variants, e.g. the accessories in a toolbox depend on the geographical location in which where the tools are sold. Therefore, the capacity complexity is high.

Another part of factory 4 produces sub-assemblies for the tools that are assembled in plant 4 and for other products that are manufactured in other Hilti plants. The plant produces around 8000 sub-assemblies. Approximately 50-100 sub-assemblies are used in the final assembly in this plant. The demand frequency can be characterized in a similar manner as the demand frequency of the final assemblies, because the same production order is used for the sub assembly items as for the final assemblies. This means that also for a large part of the sub-assemblies the demand frequency varies strongly. Typically, the products in BU 7 have a low demand frequency whereas the products in the BUs 4, 9 and 8 have a moderate demand frequency. The commonality is high, since most sub-assemblies are specific for a product family: the same sub-assemblies are used as an input for different finished goods of the same product family. Therefore, the capacity complexity is at least moderate and in some cases high. Per subassembly the product structure differs strongly: assembling a motor is completely different from assembling a grip unit. The BOM of a sub-assembly can be as large as 7 levels. Therefore, the material complexity is high.

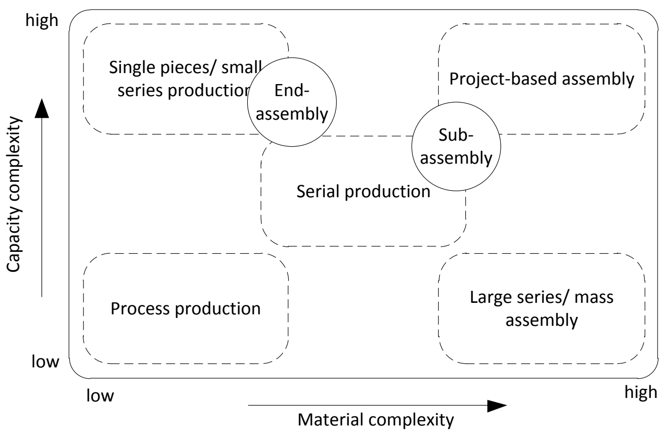


Figure 4-1: Factory characterization in terms of material and capacity complexity (Bertrand et al, 1998).

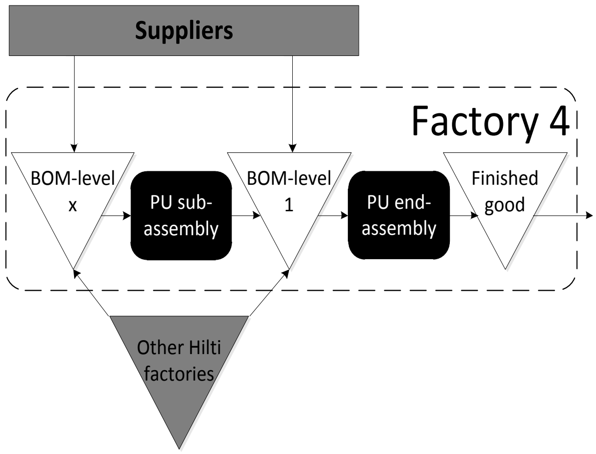


Figure 4-2: Derived control structure for plant 4.

Figure 4-1 shows that the end-assembly in plant 4 should be 'single pieces/ small series' production. This complies with the current production in the factory: there are eleven end-assembly lines and on each line different tools can be assembled. The lot-sizes differ from 4 to 20 pieces per assembly.

Based on the factory characterization, the control structure for this plant can be derived. In Figure 4-2 this derived structure is given. As indicated, there are at least two PUs: the sub-assembly and the end-assembly. Decoupling is needed if there are non-synchronized processes between successive steps; this is the case whenever a supplier delivers a component. Most of the components used are not produced in plant 4 and therefore are sourced with suppliers (both other Hilti factories as well as external suppliers). Furthermore, decoupling is necessary if there is a difference in commonality. For both the sub- and the end-assembly more than one component is necessary to make a new component, hence there is a difference in commonality. This means that plant 4 needs to decouple at least two times in the production process: at the start and between the sub-assembly and end-assembly. Furthermore, it could occur that the products are finished earlier than expected and it is possible that a truck does not arrive on time. This means that there is uncertainty in the shipping process and therefore, it is non-synchronized: decoupling at the end of chain in the factory is therefore required. As explained in chapter 2, each DP is a candidate CODP. This also holds for the DPs in the factory.

4.1.2 Selected items

The goal of the item selection method is to select those items for which the repositioning of the CODP has the largest impact. There are three measurements used at Hilti that we can use to categorize products: 1) the relative contribution to the total turnover, 2) the order frequency and 3) the order variability. In chapter 3.1 these categorization methods are explained and analyzed.

Based on the problem analysis in chapter 3, we concluded that the products that are volatile result in an uncontrollable supply chain. The volatile products are interesting to research because these products have relative higher stock and therefore their logistics costs are relatively higher than those that are not volatile. Therefore, products that are categorized as V or W are candidate for selection. In section 3.1, Figure 3-4, has been shown that V and W products do not only occur in the groups of products that have a low contribution to the sales, but also in those that have a high contribution. The products within our scope have to be manufactured in factory 4. Therefore, we use the three categorization methods to select items in factory 4: we select products from all turnover categories and focus on the categories V and W. This results in the twelve items represented in Table 4-2. In the remainder of this thesis we will use the Hilti-categories as an identifier for the item.

Hilti categories	Item	BU
T,V,R	a	8
T,W,R	b	8
A,V,R	c	4
A,W,R	d	3
A,W,S	e	8
B,V,R	f	4
B,W,R	g	8
B,W,S	h	4
C,W,R	i	3
C,W,S	j	4
D,W,R	k	4
D,W,S	l	3

Table 4-2: Products that are selected for design testing.

4.2 Final decision stage for Hilti

The goal of the thesis is to show that defining and (possibly) moving the CODP results in a controllable supply chain and that in order to reach this, not all products can be painted with the same brush in terms of service requirements. We developed the CODP-positioning framework to be able to decide on the CODP-position.

Hilti has set the service requirements as follows: a 1 day delivery with 97.5% performance for the demand through the customer service center or e-business and an immediate (0 day) delivery with 85% performance for the Hilti Centers. As discussed, all the DPs in the ideal supply chain are a candidate-CODP and the lead times between all DPs are known. In Hilti's case this would mean that for all products the CODP is either in the HC or in the CW/RDC/DC.

As mentioned previously, these service requirements are challenged because the demand per item varies vastly. This is underpinned by the fact that only 5% of the product portfolio is responsible for 80% of the total sales and by the fact that 47% of the items actually meet the service requirements. Due to a low or medium sales frequency products have a high volatility. We argue that this high volatility leads to uncontrollable stock points and that therefore the CODP for these products *should* move upstream. Should is indicated with italic formatting, because this is what is best from a logistics perspective. Moving the CODP upstream however, means that at least one of the current service requirements should change: the customer lead time will increase. This contradicts with Hilti's strategy to be close to the customer. However, it improves the reliability of Hilti towards the customer.

4.2.1 Decision tree for Hilti

A decision tree, based on the generic one depicted in Figure 2-8, is designed that aids in identifying the ideal CODP position for Hilti products. The result is shown in Appendix D- Figure 9. In this decision tree the service requirements are not input data, because the current service requirements are considered unrealistic. Instead, the service requirements are the output. We consider perspectives from different departments in the tree, such as marketing and finance. In the remainder of this section we will carefully describe the decision tree. Most steps are characterized by qualitative decisions.

Step 1: Evaluate current CODP

Step 1 addresses the volatility measurement: if the SCV of one of the item-location combination that serves the end-customer is larger than 1.77 that stock point is uncontrollable and the CODP of that item-location combination has to move upstream. If the SCV is lower than or equal to 1.77 for all item-location combinations, the CODP does not have to move. If the CODP of one item-location combination should move upstream, also others of the same item should move upstream so that the demand can be aggregated. If this is on market or regional level depends on how far we have to move the CODP upstream.

Step 2: Check source proximity

Step 2 checks how drastically the customer lead time for a region has to be increased in order to fulfill the SCV requirement. For each stock point in the supply chain the SCV is calculated for the aggregated demand in that stock point. If a SCV of smaller than or equal to 1.77 can be reached on the same continent, the lead time changes less drastically than when it should be moved overseas. Consequently, there are different decisions to be made if the CODP has to move overseas.

If the CODP can be moved upstream without going overseas, the next question is whether the most downstream candidate of the CODP is the factory or not. If it is not the factory no further decisions have to be taken: the CODP will move to that location and the customer lead time will be the expected lead time from the CODP location to the customer. If the candidate CODP is at the end of the factory, it can be checked whether it is beneficial to move the CODP upstream in the factory without changing the customer lead time too drastically. This is addressed in step 5.

Step 3: SKU management

Step 3 is designed solely for highly volatile products and products that are manufactured/ bought on a different continent than where they are sold. Actually for these products it is preferable to move the CODP to a stock point overseas to improve controllability. Yet, this is not desirable from Hilti's perspective because the customer lead time needs to increase too much. Therefore, other measures have to be taken.

First, the cause of the high volatility needs to be investigated. One cause of high volatility can be that it is a special version of another product. The specialties could vary from accessories to product types. Cannibalism occurs if there is another product in the same product family that could replace this product (at Hilti e.g. TPS vs. no TPS). If this is the case, we should remove this product from the portfolio. A lighter version of cannibalism can be that the product has a small target group due to product specifications such as stickers and manuals. Therefore, the possibility to procrastinate or to merge these specifications needs to be explored. If either of these options is not possible, we should question whether it is worth it to have this product.

If the reason of volatility is not that the product is a special version of the same product, or if postponement is not a solution, then should be decided whether the product is a value creator or not. This decision is based on input from logistics, finance and marketing/ MOs. The logistics margin and profitability as described in section 2.4.1 should be calculated. If the logistics margin is larger than 0.1 and the profitability is lower than 0.5, either marketing and/or the MOs should present profound arguments why this product should be kept. Based on that input can be decided whether a product is a value creator or not. If it is not, the product should be removed from the portfolio.

Step 4: evaluate costs-to-serve

If the product is a value creator, a market analysis is necessary to find out whether the customers are willing to wait the shipment time. If this analysis results in a negative answer, the next sub step is to calculate whether it would be profitable (enough) to fly. By sending the products by air freight the customer lead time could be decreased significantly in comparison to ship freight. However, it is important that the product stays profitable. If it is not profitable to fly, the CODP should not move overseas. This means that the volatility is still high, but based on the decision tree has been decided that it is worth it to keep the product. Because the product demand is still volatile, the customer service level should be downgraded to a more realistic value. If the customer is willing to wait the shipment time or if it is possible to fly, the CODP can be moved overseas to the factory.

Step 5: Assess factory CODP

Step 4 explores whether it is beneficial to move the CODP into the factory. Benefits can occur if there is a high component commonality with other products. If this is the case the CODP will be at a certain BOM level in the factory. Which BOM-level depends on the expected lead times of the components.

The customer lead time will be the expected lead time from the CODP stock point to the customer. If it is not beneficial to move the CODP upstream into the factory, it will be at the end of the factory. This means that the factory needs to have a finished good stock for this product and delivers if there is end-customer demand. Note that for (many of) the products that have to be shipped/ fled overseas putting the CODP at the end of the factory (or in LCN) has no benefit in comparison to placing the CODP in the CW or NDC, since no benefits of component commonality can be used. This implies that if the CODP is placed overseas in the factory, that LCN is not used as consolidation point anymore, since this enlarges the customer lead time with at least 3 days.
A remark to be made on the decision tree is that it does not take into account that the transport costs might change due to moving the CODP. Moving the CODP upstream means that both the distance and the amount of parcel deliveries increase. Parcel deliveries are more expensive than transport between the CWs and HCs. Based on the decision tree can be concluded that the CODP location should not only be based on the service requirements and volatility of a product, but also on the strategy of the organization. Usually, the strategy is reflected in the service requirements. However, in some cases it might be that the strategy or service requirements resulting from the strategy are unrealistic.

The iteration occurring in the generic decision tree cannot directly be seen in the specification for Hilti. In the tree designed for Hilti all possible iterations are addressed subsequently with specific input data per decision, we could state that it is the unfolded version. Almost every decision in the organization specific tree addresses the question whether the $SCV > 1.77$, except the SKU management step. The location of the SKU management step is different than in the generic tree. Generally speaking an organization should first ask whether the SKU can be removed, before deciding what a good CODP location is. However, in Hilti's case there is already much alignment needed with the marketing and the product portfolio departments that create 'open doors' for product segmentation, let alone removing products. Therefore, it has been a strategic decision to first check whether the CODP can be moved upstream so that the SCV is low enough. If the answer is no, then the tree directs to SKU management.

There are six different path-ends in the decision tree of which four are related to the CODP location and two are related to SKU management. With respect to SKU management there are two options: the product is removed from the portfolio or a product group/family is consolidated into one product.

The paths leading to the CODP location can be distinct, yet they do not have to lead to a different CODP. In general we can make three different groups of CODP locations: in Figure 4-3 the three possible CODP location options are shown. The purple circle indicates that the CODP is as close to the customer as possible, the green circle indicates the CODP that serves as customer aggregation location and the blue circle indicates that the CODP is in the factory.

Runners

If a product falls in the purple category, the service requirements for this product will not change. The difference between the 'runners' and 'steady products' is that 'runners' are allowed to be put on stock in the HCs.

Steady products

If a product belongs to the 'steady products', it will not be available in HCs. Customer delivery can be from the HQ WH if it is necessary to consolidate the demand from more regions (for volatility reasons. It is possible to add the HQ WH needs to be added to the supply chain if necessary. If demand consolidation up until the NDC/ RDC/ CW is already leading to a low enough volatility, the CODP will be in that location.

Specials

The last option is that the CODP is moved into the plant; to which BOM-level depends on step 4 of the decision tree.

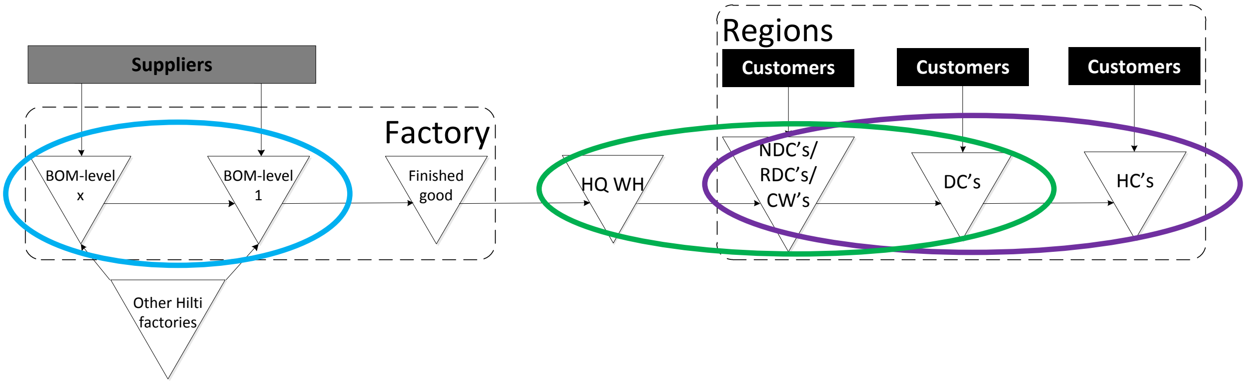


Figure 4-3: Possible CODP locations at Hilti.

4.2.2 Application of the decision tree

In Table 4-3 the resulting CODP location(s) per SKU after applying the decision tree have been given. It is out of scope for this chapter to exactly walk through the decision tree per SKU. This walkthrough per SKU can be found in appendix 0. For one item no final decision on the product segment has been made yet. The main reason is that although the product is profitable, it has only been sold twice in 2011. For another product the costs for air freight need to be evaluated.

The items in Table 4-3 are first sorted on the generated turnover category, next on variability and last on order frequency. We have applied the decision tree to the items that we have selected and we can clearly see that the designed CODP categories are applicable for certain product characteristics that are reflected by the Hilti categories. More explicitly, the item that generated high turnover (T), has medium variability (V), and has medium order frequency (R), is a runner. The item that generated a high turnover (T) in combination with a high variability (W) is a special product: we expected this because the tree is designed to filter out products with high variability. The items that generated a medium turnover (A) in combination with a moderate to high variability (V and W) are all steady products. The items that generated low-medium turnover (B) and have a medium order frequency (R) are also steady products. Next, we see that items that have a medium to low generated turnover (B,C, and D) are either candidate to remove or their CODP has to be moved upstream into the factory.

Hilti categories	Category	CODP location(s)
T,V,R	Runners	CWs and DCs
T,W,R	Specials	Factory BOM-level 1
A,V,R	Steady products	RDCs
A,W,R	Steady products	CWs
A,W,S	Steady products	RDCs, HQ WHs, CWs
B,V,R	Steady products	NDCs
B,W,R	Steady products	CWs
B,W,S	Specials	Factory BOM-level 1
C,W,R	Specials	Factory BOM-level 1
C,W,S	Remove	
D,W,R	Remove	
D,W,S	Remove or Specials	Remove or Factory BOM-level 1

Table 4-3: Simulation input, CODP locations after application of the decision tree.

The decision tree has only been applied to 12 items; this sample is too small to make generic statements from the results. However, the results clearly indicate that the Hilti categories can aid in assigning a CODP location to a product. In this way it might be possible to assign a CODP location without applying the tree, solely using the product characteristics. This can be desirable for Hilti, because it makes it fairly easy to assign a CODP location strategy to a product.

In Figure 4-4 the matrix is presented that summarizes the CODP location for the twelve items. Earlier has been stated that the categorization methods used for these SKUs are defined on global level, i.e. the categories are assigned based on the global demand. This is different than the data that can be found in most queries of the Hilti BI, because most of the queries give an indication of the categories on plant-level. One important remark is that before the matrix is used to assign a strategy to a SKU, first needs to be checked whether the SKU is candidate for removal. This check can be done by using the removal step form the decision tree. We recommend applying the decision tree for a larger sample in order to confirm this matrix, before it is implemented.

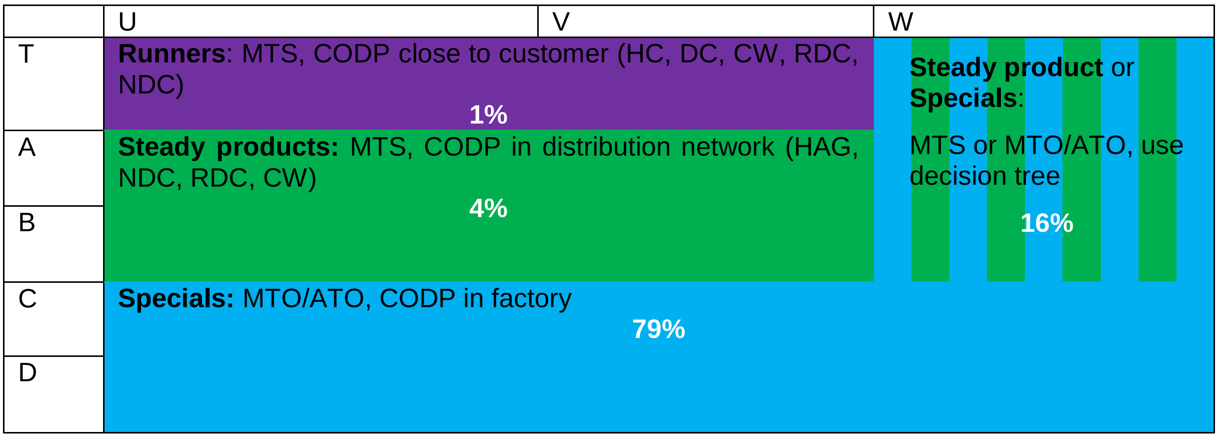


Figure 4-4: Product segmentation based on product characteristics.

4.3 Conclusion

In this chapter the CODP-framework has been applied to Hilti. There are two important differences between the general framework and the application of the framework for Hilti. The first is that the item selection for Hilti cannot be done as specified in the general framework. Therefore, existing methods at Hilti are used to select items. Secondly, at Hilti occurs the problem that the upper boundary of the CODP candidates lies further downstream than the lower boundary. In order to deal with this problem, a Hilti-specific decision tree has been developed to decide on the CODPs. The resulting policies and service requirements are organized in Figure 4-5. Although we recognized that probably the product segmentation can be made based on the categorization methods TABCD and UVW, we would like to emphasize that the tree is a powerful instrument to create awareness among employees by giving insight in the considerations that impact the decision of the CODP location. This awareness is needed because it creates a platform for implementation in the organization.

Category	CODP	Policy	Service requirements
Runners	CW/RDC/NDC+DC+HC	MTS	No change
Steady products	HQ WH and/or CW/RDC/NDC and/or DC	MTS	Extension of customer lead time 1-7 days
Specials	Factory	MTO/ATO	Extension of customer lead time 10-40 days
Remove	n.a.	n.a.	n.a.

Figure 4-5: Product segments and their characteristics.

The consequences of moving the CODP on the stock division between tiers and on the costs can be tested by simulating the complete supply chain. In the next chapter is elaborated on the design of the simulation. Chapter 6 presents the results of the simulation.

5 Experimental design

In the previous chapters is argued that currently the inventory positioning in Hilti's supply chain is uncontrolled and therefore supply chain planning needs to be redesigned. The application of the CODP-framework and the decision tree yields a redesign of Hilti's strategic supply chain planning: repositioning the CODP leads to control over the supply chain for Hilti. The simulation is used for a proof-of-concept of the redesign made. As stated in chapter 2, the output of the supply chain design should indicate inter alia how to deal with demand uncertainty. For these reasons, the purpose of this chapter is to make an experimental design to address the following: (1) The current supply chain is evaluated for the items selected, in order to prove that currently Hilti's supply chain is not optimal: decoupling should lead to improvement. (2) The current supply chain is optimized and this optimization is compared to the redesign, this gives insight in whether the redesign is better than solely decoupling.

In order to run the simulation input data is needed, to a large extend this is similar to the input data as defined in Appendix B- Table 1. However, we need to make some assumptions due to data restrictions at Hilti. Therefore, first the assumptions are addressed. Next, the simulation design for the supply chain evaluation is elaborated on. The performance of the current supply chain design as well as the value of employees handling exceptions can be evaluated. Furthermore, the difference between the current CODP location(s) and the new CODP location(s) for SKUs can be simulated. For both simulation designs we will indicate what we will simulate and what outcomes we expect.

5.1 Simulation program and assumptions

The simulation is run with the program Chainscope. For this program, the input data as identified in stage 2 of the CODP framework is needed in order to run the simulation. In this section we shortly elaborate on the program and we discuss the assumptions that have been made in order to use the program.

5.1.1 Chainscope

Chainscope is a program designed to analyse the complete supply chain of an organization, from production to distribution, from a multi-echelon perspective. With the program it is possible to analyse the current performance of a supply chain through an evaluation and it is possible to identify what the stock division should be in an optimized the supply chain. Whereas in the evaluation the average target stock is taken as fixed input data, in the optimization the inserted average target stock is ignored so that the program can calculate the optimal stock levels per tier. The program takes into account the supply chain until the last stock point owned by the organization, i.e. for Hilti this means that the transportation time from the last stock point (e.g. for Hilti the CW) to the customer and the costs of this transportation are not taken into account. Customer-location combinations can be defined and for each of this combination the expected demand and standard deviation have to be inserted. For Hilti this means that a distinction can be made between the customers that buy at HCs and those that by at DCs. Furthermore, we would like to point out that Chainscope is based on mathematical models. This means that actually it is a calculation based on the demand characteristics, not a discrete-event simulation.

5.1.2 Assumptions

Most of the data needed, as identified in Appendix B- Table 1, excluding the capacity constraints, is readily available from the BI-system at Hilti. If the data was not available assumptions have been made. In this section we profound these assumptions. Furthermore, is indicated whether it is needed to test the impact of these assumptions on the results of the simulation, i.e. the input for the sensitivity analysis is identified.

Expected lead time between stock points

The total expected lead time from one stock point to another is the goods issue at the first stock point, plus the expected transportation time, plus the goods receive at the stock point. The expected transport time between two stock points in the distribution network, is based on data directly from BI as indicated in {confidential}. Randomly, we have checked whether the expected time from the BI is similar to that indicated in the SAP. Based on that we have assumed that in the data from BI, the handling time for goods issue and goods receive in warehouses is included.

Transport costs

The transport costs for products from factories to global, national or regional distribution centers is readily available in an excel sheet from the transportation department. The price is indicated per kg and the weight of a product is known. Based on that information the price of transporting a product can be calculated. We assume that the volumes moved by Hilti are always large enough to fulfill the requirements that a minimal amount of kg needs to be moved.

The transport costs for products from global, national or regional distributions centers to Hilti Centers and/or customers is agreed upon by the local market organizations (MOs). The products in scope are distributed and sold all over the world. Furthermore, the actual price of transportation is dependent on many factors, such as whether a complete pallet, a pallet layer or a parcel is delivered. Therefore, no real cost data is used for these transportation costs. Instead, we have made an assumption based on an analysis conducted by Hilti prior to this research that indicates that the outbound transportation is on average 2.63 times higher per time frame than the inbound transportation (Hilti source).

Whether this is true in all MOs is disputable. These costs are, in combination with the handling costs, the only added costs between two stock points in the distribution network. Moreover, we calculate these costs per time frame (i.e. if the expected lead time doubles, the expected transportation costs double) and as indicated at the start of this section, also the lead time is an assumption. Therefore, it is possible that these costs and the expected lead time used as input data impact the results of the simulation. Hence the results of the simulation need to be validated by varying both the expected lead time between stock points and the costs of the transportation within a MO.

Component stock

The SKUs in scope are assembled from components that are also used in other SKUs. Thereupon, the data available from the BI is not only for this SKU, but also for the other SKUs. Therefore, a correction needs to be applied to the actual average stock of the component in order to represent only the SKU. In formula [5], a ratio has been given with which the actual average stock of 2011 has been multiplied. We assume that the multiplication is the average stock of the component that was meant for the SKU that is simulated.

$$target\ stock\ ratio = \frac{n_i * E[D_i]}{\sum_{\forall j} n_j * E[D_j]} \quad [5]$$

$i \coloneqq SKU\ that\ is\ simulated$
$j \coloneqq SKU\ that\ uses\ the\ component$
$n \coloneqq the\ number\ of\ components\ that\ are\ needed\ to\ produce\ the\ SKU$

5.2 Simulation design for supply chain evaluation

In Figure 5-1 a matrix is shown that compares the actual service rate with the outcome of the simulated service rate. A distinction can be made between the impact of human interference on the service rates and the impact of the current supply chain design on the service rates.

All results should be on the diagonal to validate the simulation: this means that the actual service rate is similar to the simulated service rate. Moreover, if a SKU can be placed in one of the squares on the diagonal, a conclusion on the impact of the supply chain design can be drawn. However, if SKUs are above the diagonal, the simulated rate is not similar to the actual rate. This can be due to human interference. We do not expect any results under the diagonal since it would be strange if the simulation performs better than the actual supply chain. If a SKU can be designated to the latter column, this means that either the design over-performs or that the employee’s interference is superfluous. In both cases this leads to higher costs than necessary, either caused by superfluous stock or by labor costs. Another topic in evaluating the current supply chain is decoupling: as explained in section 3.4 Hilti does not clearly decouple their supply chain. This should be visible in the results of the supply chain evaluation.

Actual rate / Simulated rate	$< 95.0\%$	$[\mathbf{95.0}\%; \mathbf{98.5}\%]$	$> 98.5\%$
$< 95.0\%$	Target cannot be met with current supply chain design	Beneficial human interference	Superfluous human interference
$[\mathbf{95.0}\%; \mathbf{98.5}\%]$	n.a.	Current design performs as desired	Superfluous human interference
$> 98.5\%$	n.a.	n.a.	Current design over-performs

Figure 5-1: Possible outcomes after comparison between the actual and simulated service rate.

First the human interference part is discussed in more detail, followed by debating the design part. Next we indicate how the disadvantages of not decoupling should be visible in the results of the supply chain evaluation.

Evaluating human interference

The actual service levels of the twelve products in scope are given in Table 5-1, they only hold for the locations that deliver to the customer with a 1 day lead time and 97.5% service reliability. The data for the service in HCs is not available, due to the following: the HC functions like a retail store: the customer walks in, buys a product and takes it home directly. If the product is not available in the HC, the employee or the customer can contact the customer service center to order the product. In this case, the availability at the HC was 0, but the customer still gets served through another Hilti sales channel. Whether and how often this happens is not measured and therefore, the failure rate of the HC is probably higher than that the data of 2011 currently indicates. Therefore, the comparison between the actual and simulated service rate for HCs is not made.

Item	ATS_%	Item	ATS_%	Item	ATS_%
a	100.0 %	**e**	96.0 %	**i**	100.0 %
b	97.7 %	**f**	98.7 %	**j**	66.7 %
c	98.4 %	**g**	95.5 %	**k**	70.0 %
d	95.5 %	**h**	94.3 %	**l**	100.0 %

Table 5-1: Average service rate for the CWs, RDCs and NDCs per SKU in 2011.

Furthermore, we pinpoint that in some cases the average service level in 2011 was higher than the acquired service level. From the table can be read that five tools had a higher service level than needed. If a service level is higher than needed, then probably the stock in the distribution network of these SKUs was higher than needed. In other words: if the stock of these SKUs is lowered, still the desired service levels can be met but against lower costs. However, we must not forget that these tools can have a SCV in the different stock keeping locations that is higher than the maximum of 1.77. If this is the case, the results of the simulation can be unreliable, since it is based on an analytical model. All analytical models become unreliable if the SCV is too high. The second part of the simulation assesses this problem by applying the decision tree designed in chapter 4.

On the other hand it could also be the case that the actual service level in 2011 was higher, than what it analytically could have been. Generally, we can assign this difference to human interference. By means of employees interfering in both the planning and the execution process, the resulting service level can be higher than the result without interference. Partly, this is an advantage; in the end employees are paid to deal with exceptions and cope with problems that models cannot cope with. However, if this interference has to happen too often, this can become costly. Uncontrollability can be a cause for the frequent necessity of human interference.

Additionally, the supply chain can be optimized for the desired service requirements, in order to create an insight for Hilti in the costs of the desired service requirements (although we argue that the current desired service requirements are unrealistic, lead to uncontrollable stock points and thereby, should change as indicated in section 2 of this chapter). We have indicated earlier in this section that the actual service rate might have been higher than the evaluated service rate, thanks to human interference. The costs of the optimized supply chain with and without human interference can be compared. If the simulated rate of the supply chain evaluation is lower than 97.5% and if the actual rate is 97.5% or higher, then human interference increased the service rate to one that was desired (or even a higher one). We can assume that the increase in service rate due to human interference will also occur if the chain would be optimized. This would mean that we simulate the optimization with a target rate that was the result of the initial evaluation of the supply chain. However, human interference does come at a price. It is difficult to make a cost estimation of this interference, because it is not exactly known where in the process and how often it takes place

By comparing these two results, insight can be given in whether it is worth to have human interference or whether it is better to design the supply chain so that it can meet the service requirements without any human interference. In the latter case it does not mean that human interference does not take place anymore: there can always be exceptions and human interference is needed to cope with that.

Evaluating the supply chain design

By dividing the SKUs over the different squares in the matrix an insight is created in the controllability of the supply chain. More explicitly we can state that if there are many items in the upper right or lower left square of the matrix, this indicates that the current supply chain design does not make the needed distinction between SKUs.

In chapter 3 is discussed that the current supply chain design leads to uncontrollable stock points for those items that have high variability. In the item selection we deliberately selected items with moderate to high variability. Therefore, we expect for the selected items that they are concentrated especially in the upper left and lower right squares in the matrix.

Evaluating the benefits of decoupling

Furthermore, in chapter 3 has been indicated that currently Hilti does not clearly decouple the supply chain. Whybark & Yang (1996) proved with a discrete-event simulation that the inventory should be positioned as much downstream as possible in order to achieve a high service rate. Therefore, we expect that in the results of our simulation indeed most stock is positioned downstream based on the current service requirements. If Hilti does not clearly decouple then this should be visible by the fact that not only the most downstream tiers contain stock. Moreover, another observation is that in plant 4 the end-assembly of most items is a Just-In-Time (JIT) process, which means that there is not a standard replenishment cycle but that the factory has to produce the SKU within 3 days after a 'replenishment demand order' has arrived. I.e. if LCN reorders an item, this item needs to be produced and put on transport to LCN within 3 days. Besides the JIT process, also the purchasing and planning process have influence on the component stock. Usually, the number of components coming from the in-house production of the factory where the end-assembly takes place is relatively small. I.e. a relative large amount of the components is sourced with suppliers.

It should be visible in the results of the evaluation that Hilti does not really decouple: we expect that the current division of stock among the different tiers does not always benefit the perceived end-customer service. Moreover, by not aggregating the end-customer demand (because there is no real decoupling) the factories currently have a higher variability of orders than necessary and this leads to a higher component stock than necessary.

5.3 Simulation design for testing the redesign

The second part of the simulation is a proof-of-concept for the CODP framework and decision tree as applied to Hilti. As indicated in section 4.2 there are three possible outcomes with respect to CODP locations after applying the Hilti-specific decision tree. In Table 4-3 the resulting CODPs for the twelve items in scope have been given. This indicates what situation will be simulated per SKU.

The results of the simulation for the new CODP can be compared with the results for optimizing the supply chain with the former CODP. We expect that the stock levels per tier will change if the CODP is moved upstream. More explicitly: the stock levels of the locations downstream the CODP will be zero and the stock level of the CODP will be high. Furthermore, we expect that moving the CODP results in, besides a controlled supply chain, cost savings.

5.4 Conclusion

The purpose of this chapter has been two-fold: firstly we showed that a simulation is a powerful tool for generating insight in the complex, complete supply chain. First, the design of the current supply chain is evaluated. Here we address three topics: (1) the impact of human interference in the current chain; (2) the current design is not tailored to Hilti's customer-needs and this should be visible in the results of the evaluation; and (3) the current supply chain has no strict decoupling and the disadvantages should be visible in the results of the evaluation.

The second part of the simulation consists of evaluating the supply chain if the redesign would be implemented. We expect that the redesign results in additional savings, above implementing decoupling, in stock value and quantity. Moreover, by implementing the redesign the supply chain will be controlled. In the next chapter the results of the simulation are shown.

6 Results

As elaborated on in the previous chapter, the results of the simulation consist of two parts. First the current supply chain is evaluated and thereafter the redesign is tested. In the evaluation three topics are addressed: (1) impact of human interference in the current chain; (2) control of the current chain; (3) decoupling.

The second part of the simulation consists of evaluating the supply chain if the redesign would be implemented. We expect that the redesign results in additional savings, above implementing decoupling, in stock value and quantity. Moreover, by implementing the redesign Hilti can regain control over the supply chain.

6.1 Supply chain evaluation

6.1.1 Human interference and supply chain design

The evaluation of the simulation uses the real average stock levels of 2011 as a guideline. I.e. the average stock levels of 2011 per location are exactly simulated by the program. Therefore, the evaluation gives insight in what the maximum service level could have been in 2011, based on the calculations and planning model in the simulation. However, in real life employees intervene in the process and thereby maybe increase the actual service level. Moreover, the supply chain design could be not fulfilling the service requirements, because the design is unrealistic.

Simulated rate \ Actual rate	$< 95.5\%$	$[95.5\%; 98.5\%]$	$> 98.5\%$
$< 95.5\%$	Item h Item j Item k	Item b Item c Item e	Item i Item l
$[95.5\%; 98.5\%]$		Item g	
$> 98.5\%$		Item d	Item a Item f

Figure 6-1: Result supply chain evaluation of ready rate.

In chapter 5 we introduced the comparison matrix; based on the results of the simulation we can designate the different items to a square. The exact numbers can be found in appendix F. In Figure 6-1 can be seen that only one product can be assigned to the middle square. This is concerning because as indicated in the previous chapter, this is the square where all the products should be if the strategic supply chain would be designed correctly. Furthermore, there are three cases of 'beneficial human interference' and there are four cases of 'superfluous human interference'.

The results confirm that there are products in the upper left or lower right square. This is an indicator of the fact that the current supply chain design does not make the needed distinction between SKUs. I.e. the current supply chain design results in an attempt to control uncontrollable stock points, which is impossible. A redesign that makes a distinction between SKUs based on their product characteristics is necessary, in order to make the supply chain controllable. It is remarkable that the simulated rate of item d is higher than the actual rate. In 2011, one of the two CWs where the product is stored was unavailable for a period of time, due to a fire. In the simulation this event is not taken into account and the unusual material flows have been designated to the 'normal' path. However, in real life many SKUs were destroyed by the fire. Therefore, the real ATS is probably lower than what it would have been without the fire.

6.1.2 Improvement through decoupling

In section 3.4 has been indicated that currently Hilti does not clearly decouple its supply chain. This should be visible in the results of the evaluation as well: we expect that the current division of stock among the different tiers does not always benefit the perceived end-customer service. Inter alia by not aggregating the end-customer demand but allowing the actual customer order to enter the factory, the factories currently have a higher variability of production orders than necessary and this leads to a higher component stock than necessary.

In equation [6] a ratio is given with which can be measured whether decoupling changes the stock per tier. The ratio is high if the relative stock downstream from (and including) the CODP is high in comparison to the complete chain. The ratio is calculated for both, the value of the stock and the amount of stock. Table 6-1 shows the ratio before and after applying decoupling (i.e. evaluation versus optimization). All SKUs except one have a relative stock that is both in value as in quantity higher with than without decoupling. This means that due to decoupling more stock is held at the CODP and less upstream from the CODP than without decoupling.

$$\frac{\sum_{\forall p=CODP's} S_{i,p=CODP's}}{\sum_{\forall i,p} S_{i,p} + \sum_{\forall c,p} S_{c,p}} \quad [6]$$

	evaluation		Decoupling in old design	
	#	value	#	value
Item a	0.00	0.77	0.05	0.92
Item b	0.00	0.59	0.00	0.34
Item c	0.00	0.21	0.13	0.26
Item d	0.00	0.68	0.04	0.93
Item e	0.00	0.53	1	1
Item f	0.02	0.76	0.76	0.99
Item g	0.01	0.69	0.26	0.99
Item h	0.03	0.84	0.52	0.99
Item i	0.01	0.59	0.65	0.99
Item j	0.00	0.12	0.06	0.92
Item k	0.07	0.18	0.43	0.98
Item l	0.00	0.01	0.33	0.99

Table 6-1: Change in relative stock due to decoupling.

Furthermore, the calculation of the needed component stock works differently in MRP than in the simulation program that we use. The simulation uses the synchronized base stock (SBS) policy. This policy suggests base stock levels based on the expected lead time of the components. In general, if lead times per component differ extensively and if lead times are long, the SBS policy leads to large savings in base stock quantity. The difference between how MRP calculates the needed stock and how SBS does that is explained with an example in the attachment F. The type of stock that is superfluous according to the SBS policy is called dead stock.

Table 6-2 represents the relative amount of dead stock per item for the production process, in average number of stock and average value of stock. We have made a distinction between the first BOM level in a factory and the other BOM levels, because the first BOM level is the end-assembly of the tool (which is in most cases a JIT process), whereas the other BOM-levels are the in-house production of components.

The expectation is confirmed by the simulation: for all twelve items the components contain dead stock. The results show that nine out of twelve items have a relative dead stock value on BOM level 1 of more than 50% of the total stock value for the components of this item. This means that for these items more than half of the component stock does not contribute to the end-customer service rate. Moreover, for some SKUs the value of the dead stock is more than 90% of the actual stock. On top of the fact that there is a waste of value of these components, every component occupies space in the warehouse. Therefore, there is not only a value waste but there is also a space waste. We have to take into account however, that the actual stock that has been used for the calculation, is based on the target stock ratio as defined in 5.1.2. This seems a good approach however; we need to be cautious with drawing conclusions. Therefore, we conclude that it is worth it to at least investigate the potential of the SBS policy and that probably this will leave to savings.

		Dead stock relative to actual stock				Dead stock relative to actual stock	
		#	CHF			#	CHF
Item a	BOM 1	92%	97%	Item g	BOM 1	67%	58%
	other BOMs	78%	34%		other BOMs	99%	100%
Item b	BOM 1	11%	72%	Item h	BOM 1	51%	23%
	other BOMs	14%	50%		other BOMs	61%	69%
Item c	BOM 1	90%	96%	Item i	BOM 1	92%	70%
	other BOMs	64%	74%		other BOMs	94%	94%
Item d	BOM 1	91%	99%	Item j	BOM 1	81%	85%
	other BOMs	89%	92%		other BOMs	77%	56%
Item e	BOM 1	82%	62%	Item k	BOM 1	88%	37%
	Other BOMs	83%	67%		other BOMs	47%	48%
Item f	BOM 1	53%	24%	Item l	BOM 1	84%	80%
	other BOMs	76%	68%		other BOMs	60%	58%

Table 6-2: Relative dead stock in current supply chain.

6.2 Strategic supply chain redesign: results of product segmentation

In this section we zoom in on the results after the application of the decision tree. We devote different sections to the different product segments. The purple category is not treated here, because for this category the CODP does not change in comparison with the current situation, therefore the previous section that indicates the impact of decoupling suffices. The red category is also not represented, since we advise to remove these products from the portfolio.

Firstly, the 'steady products' and thereafter, the 'specials' are elaborated on. In the 'specials' are also the cases for which we doubted between 'CODP in factory' (blue) and 'remove item' (red). In each section we have the following structure. The section is started with an overview of the products and there new CODP locations. Thereafter, a summary of data on all items in the category is given.

6.2.1 Results for steady products

As indicated in the introduction of this section, we first give an overview of the items that belong to this category; the overview can be found in Table 6-3. In the same table the proposed CODP locations are also mentioned. If an item has more than one proposed CODP location, this does not mean that there are different options: each CODP location is then unique for an item-location combination. Furthermore, also the new customer lead times according to the current available data from Hilti is indicated.

If the CODP moves upstream only one location, this means that the customer lead time for HC customers will be similar to that of CW/RDC customers: a maximum of 1 day. If the CODP moves upstream more than one location, the current expected lead times are going to be the customer lead times.

SKU	legend for Figure 6-2 and Figure 6-3	CODP location(s)	Customer lead time (respectively per CODP location)
Item c		RDC 8110	1 day
Item d		CW 0900 and CW 0980	1 day
Item e		RDC 0650, HQ 0570, CW 4100, CW 9200	1-2 days; 6-35 days; 11-20 days; 1 day
Item f		NDCs (6000 and 6004)	1-7 days
Item g		CW 2100	1 day

Table 6-3: Steady products with their proposed CODP locations.

In Figure 6-2 and Figure 6-3 the costs and the service rate per SKU are shown. Each scenario is indicated by a different shape and each SKU is indicated by a different color. The annual costs consist of the cost of capital, the material cost, the cost of dead capital (caused by dead stock) and the annual release costs. The total investment consists of the average stock, the dead stock and the in transit stock.

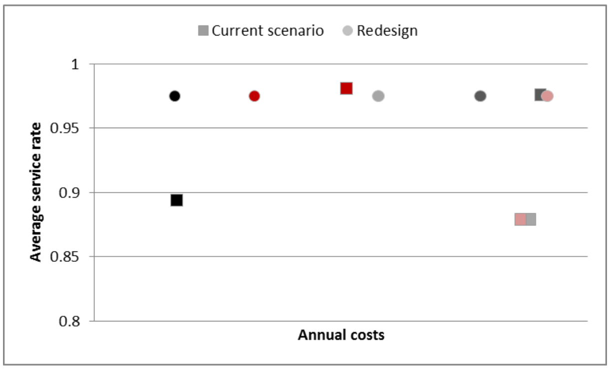


Figure 6-2: Annual costs vs. average service rate per scenario per SKU, steady products.

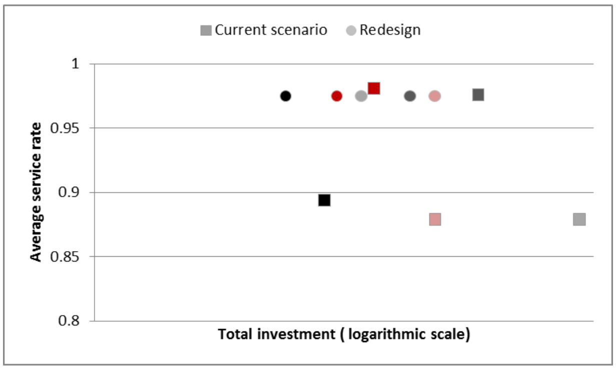


Figure 6-3: Total investment vs. service rate per scenario per SKU, steady products.

From the graphs can be read that in all cases the service rate in the redesign is exactly 97.5%. The other scenario does not have this service rate, because also HCs are included (and they have a target rate of 85%). Furthermore, from the figures can be read that the redesign in nearly all cases results in lower costs.

Table 6-4 summarizes the relative average differences per cost center for all the SKUs in the 'steady products' category. The costs of the new CODP location are compared with the current costs according to the simulation. The total stock will decrease if the product segmentation is applied. The only cost not reflected in the results of the simulation, is the delivery from the last stock point to the customer. If a product is sold in a HC, there are no delivery costs because the customer collects the product themselves. These costs need to be detracted from the savings. As the savings are so large, we expect that there still will be cost-savings even if the extra parcel deliveries have been detracted.

	Comparison with current situation
Cost	
Annual cost of capital	-77%
Annual cost of dead capital	-100%
Annual release cost	-89%
Total annual cost	-17%
Investment	
Stock on hand	-85%
Dead stock	-100%
Total Investment	-40%
Days on Hand	
Actual ready rate	From 92.2% to 97.5%
Stock on hand	-85%
Dead stock	-100%
Total stock	-78%

Table 6-4: Average cost differences and supply chain characteristics for the 'steady products'.

6.2.2 Results for specials

In Table 6-5 the new customer lead times for the SKUs that belong to the 'specials' are presented. The new CODP-location will be in the factory at BOM-level 1 for all the SKUs in this category.

SKU	legend for Figure 6-4 and Figure 6-5	CODP location(s)	Customer lead time
Item b		Factory BOM-level 1	10-13 days
Item h		Remove or Factory BOM-level 1	30-32 days (overseas)
Item i		Factory BOM-level 1	44-48 days (overseas)
Item l		Remove or Factory BOM-level 1	35 days (overseas)

Table 6-5: Items in 'specials' with their proposed CODP locations.

In Figure 6-4 and Figure 6-5 the costs and the service rate per SKU are shown. Each scenario is indicated by a different shape and each SKU is indicated by a different color. The annual costs consist of the cost of capital, the material cost, the cost of dead capital (caused by dead stock) and the annual release costs. The total investment consists of the average stock, the dead stock and the in transit stock.

From the graphs can be read that in all cases the service rate in the redesign is exactly 97.5%. The other scenario does not have this service rate, because also HCs are included (and they have a target rate of 85%). One SKU has due to the redesign higher annual costs and investment costs than currently. For SKU, the service rate for the CWs in the current situation should be 94.1% according to the simulation. This means that the service rate has to increase quite a lot (to 97.5%) if we optimize the stock levels for the product segmentation. Increase of the service rate means increase of the stock. This could be an explanation of the vast stock increase for this product.

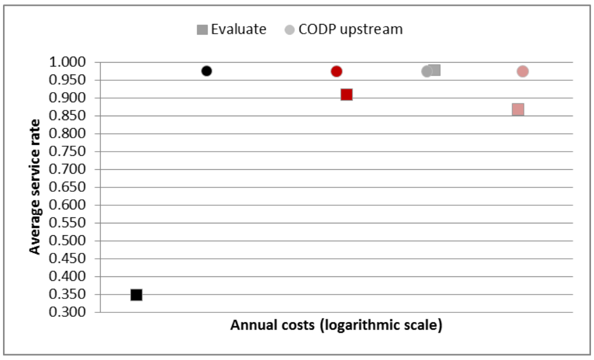


Figure 6-4: Annual costs vs. average service rate per scenario per SKU, 'specials'.

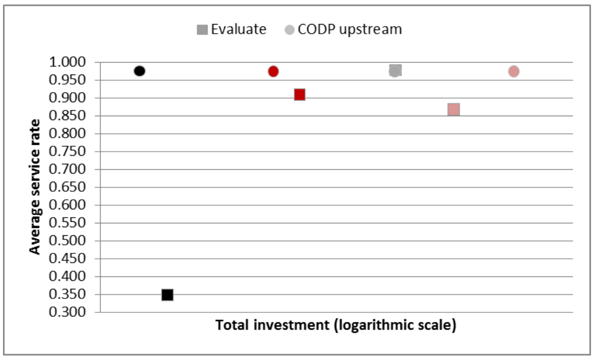


Figure 6-5: Total investment vs. average service rate per scenario per SKU, 'specials'.

Table 6-6 summarizes the relative average differences per cost center for all the SKUs in the 'specials'. The costs of the new CODP location are compared with the current situation. The total stock will decrease if the product segmentation is applied. The total annual cost and the total investment increase, but in return the supply chain will be controllable again. However, if we do not include the SKU with a vast stock increase, the total annual cost and the total investment decrease in comparison with the current situation. This is not visible in the average indicated in Table 6-6; Table 6-7 shows the average cost savings for the other three items.

From the results of the strategic supply chain planning redesign can be concluded that, next to the fact that the supply chain will be controlled again, the redesign leads to both stock and cost savings. Moreover, the simulation has been executed per SKU. Therefore, the benefits that should be gained from sharing the component stock with other SKUs are not visible. The simulation is run per SKU: the benefit that can be achieved by the commonality in component stock with other SKUs is not represented in the results.

	Comparison with current situation
Cost	
Annual cost of capital	107%
Annual cost of dead capital	-100%
Annual release cost	-48%
Total annual cost	3%
Investment	
Stock	149%
Dead stock	-100%
Total Investment	107%
Time	
Actual ready rate	From 78% to 97.5%
Days on hand	149%
Dead stock	-100%
Total stock	-11%

Table 6-6: Average cost differences and supply chain characteristics for the 'specials'.

	Comparison with current situation
Cost	
Annual cost of capital	-7%
Annual cost of dead capital	-100%
Annual release cost	-58%
Total annual cost	-10%
Investment	
Stock	-11%
Dead stock	-100%
Total Investment	-7%
Time	
Actual ready rate	From 78% to 97.5%
Days on hand	-11%
Dead stock	-100%
Total stock	-29%

Table 6-7: Average cost differences and supply chain characteristics for the 'specials', excluding one case.

6.3 Robustness of the results

As discussed in chapter 5.1.2, some assumptions had to be made for the input data used in the simulation. We have indicated that the assumptions on the expected lead times between stock points in the distribution network and the transport costs for the MOs could influence the results. The robustness of the results can be checked by a sensitivity analysis. It is expected though, that only the costs will be influenced. Therefore, it is not expected that the conclusions from the results with respect to the redesign and to decoupling will change. With testing the robustness of the results, not only the results are validated, but also insight is given in the impact of the two variables (lead time in distribution network and local transport costs).

6.3.1 Impact lead time

The impact of the lead time is tested, because assumptions have been made about the data used as input for the simulation. It could be that the real expected lead time is higher or lower than the data used for the simulation. Therefore, the impact of changing the lead time in the distribution network is tested by creating the following four scenarios: (1) decrease of 50%, (2) decrease of 25%, (4) increase of 25%, (5) increase of 50%. In the displayed results scenario (3) is the original value.

Changing the lead time in the distribution network is predicated to have impact as follows:

- The lower the lead time, the less stock in transit (because $IT = L * \mu$). This means that the value of the total inventory decreases and thereby costs will be saved.
- The lower the lead time, the lower the Safety stocks (SS is dependent on lead time: $SS = k\sigma\big(D(0, L)\big)$, where L is the expected lead time in periods of time). Therefore, the value of the total inventory decreases and thereby costs will be saved.
- The lower the lead time, the faster the distribution network can react.
- If the CODP is advised to move upstream, the new customer lead time will be lower.

	(1) -50%	(2) -25%	(3) Base	(4) +25%	(5) +50%
Total annual costs	0%	0%	0%	0%	1%
Total Investment	-7%	-4%	0%	5%	11%
Total stock (time)	-9%	-4%	0%	5%	10%

Table 6-8: Impact of changing the lead time between stock points in the distribution network.

Table 6-8 shows the results of varying the lead times. Based on the results point 1 and 2 can be confirmed. However, the impact is not as high as expected, especially on the annual costs. The results may contain some rounding errors: the expected lead time has to be rounded to the nearest integer.

6.3.2 Impact transport costs

The impact of the transport costs is reviewed, because assumptions have been made about the input data: it is assumed that the transport costs of local parcel delivery are 2.63 times more expensive per lead time:

$$c_{L,i} = c_{G,i} * \frac{L_{L,i}}{L_{G,i}} * 2.63$$

Where:
$c_{L,i} = local\ transport\ costs\ for\ item\ i;$
$c_{G,i} = global\ transport\ costs\ for\ item\ i;$
$L_{L,i} = local\ expected\ lead\ time\ for\ item\ i;$
$L_{G,i} = global\ expected\ lead\ time.$

In the sensitivity analysis the factor 2.63 is changed in order to check the impact of this factor. It is expected that the material costs decrease if the factor decreases, because the transport costs are seen as added value between stock points. Furthermore, the value of the in transit stock is expected to decrease as the factor decreases. The following scenarios are simulated: (1) 1.5, (2) 2, (3) 2.63, (4) 3, and (5) 3.5.

	(1) 1.5	(2) 2	(3) 2.63	(4) 3	(5) 3.5
Total annual cost	0%	0%	0%	0%	0%
Total Investment	0%	0%	0%	0%	0%
Total stock	0%	0%	0%	0%	0%

Table 6-9: Impact of changing the factor that determines the local transport costs.

Table 6-9 shows that changing the factor that is used to calculate the local transport costs not impacts the results of the simulation.

6.4 Conclusion

The purpose of this chapter is two-fold. The current supply chain has been evaluated and the redesign has been tested. The evaluation has led to insights on whether human interference takes place and on whether decoupling is beneficial. From the evaluation can be concluded that Hilti's inventory management is not under control: the supply chain design over- or underperforms strongly for products with high variability. Through decoupling and implementing the SBS-policy savings can be made. However, the supply chain remains uncontrollable if no product segmentation for stock positioning is applied.

Moving the CODP upstream does lead to a controllable supply chain and therefore, Hilti can be in control of their supply chain if they use the CODP framework and the decision tree. In the simulation results has been shown that moving the CODP upstream leads to less stock in general. Moreover, costs will be saved if the CODP is moved upstream in the distribution network. We expect that due to component commonality with other SKUs also costs can be saved if the CODP is moved into the factory. However, this was not visible in the results of the simulation.

Furthermore, the impact of changing the lead time in the distribution network and of changing the transport costs in the local distribution network has been tested. As expected, the lead time between stock points in the distribution network has an impact on the costs and the amount of stock in the supply chain. This means that shortening the lead time saves costs aside to the fact that it improves (i.e. shortens) the customer lead time if the CODP is moved upstream. Changing the factor that aids in calculating the local transport costs does not impact the results of the analysis.

7 Implementation of redesign

The change the organization needs to go through in order to implement the recommended redesign is large. Implementing a product segmentation is a paradigm shift for the organization. Therefore, before physical implementation of the product segmentation, a controlled change management process is needed. We suggest that the culture change is carefully planned: if the implementation is not successful now, it is unlikely that a similar redesign is accepted in the (near) future. In section 7.1 we shortly elaborate on a suggestion for the change management process.

We would like to emphasize however, that the aim of this thesis is to present the redesign and convince that it leads to desirable results. We recognize the fact that change management is necessary, but we choose not to elaborate thoroughly on the change management process. We do elaborate more extensively on the actions and tasks that need to be taken in order to implement the product segmentation. These actions can be undertaken partly *parallel to* the change management process and partly *after* the change management process.

There are two concepts that GLM together with other departments can implement. The first concept is decoupling in general: currently Hilti does not really decouple and this is one cause of high stock along the chain. We have discussed in chapter 2 how the supply chain can be decoupled in general: which models can be applied in the upstream part of the CODP and which can be applied downstream from the CODP. The second concept is a product segmentation that leads to a controllable supply chain. The implementation of this concept is the most impacting one. Section 7.2 gives the actions that need to be taken to implement the product segmentation.

7.1 Change management

Organizational change is the process by which organizations move from their current state to some desired future state to increase their effectiveness. The goal of planned organizational change is to find new or improved ways of using resources and capabilities in order to increase an organization's ability to create value and improve returns to its stakeholders (Jones, 2007). Managers face impediments to the change on all hierarchical levels in the organization. Kotter (1996) suggests an eight-stage process that gives guidance to change in an organization. The eight stages are as follows:

1. Establishing a sense of urgency;
2. Creating the guiding coalition;
3. Developing a vision and strategy;
4. Communicating the change vision;
5. Empowering employees for broad-based action;
6. Generating short-term wins;
7. Consolidating gains and producing more change;
8. Anchoring new approaches in the culture.

For some of the stages already content can be drawn up, based on the thesis. The sense of urgency is addressed thoroughly in chapter 3: without the product segmentation there are uncontrollable stock points which are tried to be controlled. This is impossible and leads to high costs and unreliable service rates. In order to guard the alignment between departments, the guiding coalition should include at least a marketing depute, a sales depute, a factory depute and a logistics materials management depute. Also the direction of the vision is developed in this thesis: SKUs should be treated differently based on their demand characteristics. Furthermore, some short-term wins have also been indicated: by dividing the stock differently over the tiers cost benefits are gained.

7.2 Product segmentation

To implement the product segmentation at Hilti, several actions need to be taken:

1. **Design the alignment process between the strategic, tactical and operational level**
   The redesign on strategic level can only be implemented correctly if the communication between the strategic, the tactical and the operational level is correct. In chapter 2.2 we have elaborated on how the supply chain should be organized from this perspective. This chapter can be taken as a basis for the alignment process. Special attention needs the translation into

the tactical and operational level in the manufacturing part: the factories will have to deal with a hybrid MTO/MTS environment.

2. (a) **Create a tactical level**

Currently, a tactical level that controls the complete supply chain is missing. In order to make the design work, several decisions on tactical level need to be taken, as described in chapter 2. A part of the global material managers could take the role on tactical level.

2. (b) **Education and training**

Staff needs to be trained to understand what decoupling and controllability are and how it impacts the organization and the roles.

3. (a) **Update task descriptions**

Task descriptions for the staff need to be updated to reflect their updated roles and responsibilities. Roles that specifically need updating are those of the material managers in the distribution network, the MO general manager, the product portfolio manager and the factory materials manager ('scheduler').

3. (b) **Redefine key performance indicators (KPIs)**

KPIs need to be refined for both monitoring the supply chain and for realizing the HPM alignment:

- Supply chain KPIs to update: ATS and CPOi should only be measured for the SKUs that are actually held on stock in the stock point.
- Three mechanisms of HPM alignment can be distinguished: joint reward systems, liaisons and spatial proximity ((Aschenbaum et al, 2009), (Zhao et al, 2011), (Koulikoff-Souviron & Harrison, 2010)). KPIs can be defined such that these mechanisms are supported.

4. (a) **Adjust SAP**

The SAP (APO and R/3) and BI system supporting the supply chain are to be updated:

- to reflect the newly decoupled supply chain;
- to monitor the updated KPIs;
- and to reflect the refreshed roles and responsibilities.

4. (b) **Update customers**

A detailed marketing plan that informs customers about the product segmentation needs to be made.

5. **Adjust inventory positions**

A detailed overview of the updated product distribution in the supply chain and the related required inventory setup is required for this exercise and also needs to be communicated to all relevant managers and their staff.

Figure 7-1 gives a process overview of the actions. We suggest that first pilots are made, before the product segmentation is implemented globally. This is our view on the implementation, but Hilti can also choose a different path.

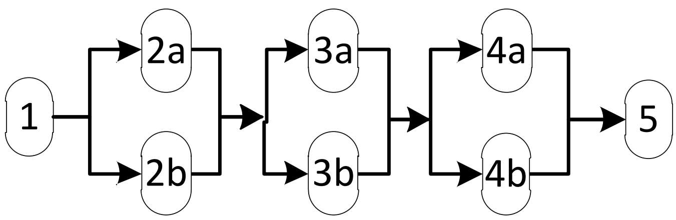


Figure 7-1: Process overview of implementation plan actions.

8 Conclusions and recommendations

Hilti faces high inventories and unstable service rates, because they try to control uncontrollable stock points. Due to Hilti's large product portfolio SKUs have different demand characteristics. This is not problematic, as long as the SKUs are not all treated similarly.

First, the research questions will be answered. This gives a conclusion on the relevant results for Hilti. Furthermore, rigorous conclusions can be drawn. These are described in the second section. Based on the rigorous conclusions, suggestions for further research are given in section 3. Furthermore, there are some managerial insights that have resulted from the analysis, which were not part of the research questions. These insights are summarized in section 4: additional recommendations.

8.1 Answers to the research questions

The research questions of this thesis were as follows.

1. What product segmentation needs to be adopted so that the stock points become controllable and the supply chain is in control? What should be the position of the CODP per product segment to make the current situation controllable?
2. What consequences does the change of the CODP position have for the customer service requirements? And for the costs?
3. What consequences are there for steering strategies after placement of the CODP? I.e. how is the strategic decision of placing the CODP translated into the tactical and operational level?

Table 8-1 gives an overview of the proposed product segmentation and the possible CODP positions per product segment (which answers the first question). Furthermore, the change in service requirements is indicated in the table, which partly answers the second question. In all cases the service rate remains the same (97.5% for SKUs delivered from HQ WHs, CWs, RDCs, NDCs and DCs and 85% for SKUs in HCs), but the customer lead time changes as the CODP moves upstream. Typically this means that 'runners' have a customer lead time of 1 day if the product is ordered at the CW, RDC, NDC or DC, or 0 days if the product is bought in the HC. The 'steady products' have a customer lead time of 1-7 days; the expected lead time form the HQ WHs, CWs, RDCs, NDCs or DCs. The 'specials' have a customer lead time of 10-40 days; the expected lead time of assembling and sending the SKU to the customer. The steering strategies can be derived from the policies, as described in chapter 2.

Segment	CODP	Service requirements		Policy	% of total products
		Service rate	CLT		
Runners	CW/RDC/NDC+DC+HC	No change	No change	MTS	1%
Steady products	HQ WH or CW/RDC/NDC or DC	No change	Extension to: 1-7 days	MTS	12%
Specials	Factory	No change	Extension to: 10-40 days	MTO	87%
Remove	n.a.	n.a.	n.a.	n.a.	unknown

Table 8-1: Product segments and their characteristics.

Based on a simulation of the complete supply chain, we were able to calculate potential cost savings of the product segmentation. There are some differences between how Hilti's supply chain operates and how the tool works. The tool assumes that the supply chain is decoupled and applies the synchronized-base-stock policy. The synchronized-base-stock policy is applied on the component stock of assembly items which leads to savings in the component stock. Therefore, the calculated cost savings include this policy and if this policy is not implemented they will be lower. Furthermore, in the current situation there are no delivery costs if a product is sold in a HC, because the customer collects the product themselves. These costs need to be excluded from the savings. However, as the simulated savings are large (see Table 8-2), we expect that there still will be cost-savings even if the extra parcel deliveries are included.

Cost	
Annual cost of capital	-73.5%
Annual cost of dead capital	-100.0%
Annual release cost	-76.6%
Total annual cost	**-16.1%**
Investment	
Stock on hand	-81.9%
Dead stock	-100.0%
Total Investment	**-35.4%**
Time	
Actual ready rate	7.6%
Stock on hand	-81.9%
Dead stock	-100.0%
Total stock	**-62.6%**

Table 8-2: The difference in costs between the current situation and the product segmentation.

8.2 Conclusions related to literature

Controllability

In this thesis, controllability has been marked as an important input parameter for strategic supply chain planning. We also state that the location of the CODP depends on the controllability of stock points. This is an important conclusion because in supply chain management literature controllability has not yet been defined, nor has controllability been marked as an important input parameter for deciding on the CODP.

Tools: CODP framework and decision tree

- The CODP framework:
  is a practical tool that has been introduced to evaluate and decide on the CODP location. The framework is needed to identify whether there is a gap between the upper boundary of a CODP (based on the service requirements) and the lower boundary of the CODP (based on the controllability of stock points).
- Generic decision tree:
  In case of a gap between the above-indicated boundaries, i.e. the upper boundary is located further downstream than the lower boundary, other decisions have to be made in order to gain control of the supply chain. The generic decision tree is a tool that aids in making those decisions.

For Hilti, the outcomes from these tools were extremely useful. Whether the tools are applicable for other organizations, has not been looked at, but they are designed in such a way that that should be the case. Based on the rigorous conclusions possibilities for further research can be indicated

8.3 Further research

There are opportunities for further research in the area of controllability; it would be interesting to research on a larger scale how the service rate is impacted by uncontrollability. Furthermore, there has been a proof-of-concept of the CODP framework in this thesis, but it has only been applied to one organization. Therefore, researching whether the CODP framework and the accompanying decision tree can be applied to more organizations in different environments, will give insight in the generality of the framework and decision tree. Furthermore, we have measured the benefits of applying the CODP framework by means of a simulation program. We were not able to actually implement the redesign within the time-frame of this project. The actual results of implementing the product segmentation that follows from the CODP framework could give interesting insights.

8.4 Additional recommendations for Hilti

Besides the product segmentation, there are some managerial insights that have resulted from the analysis conducted. We recommend that in the near future Hilti gives attention to the following topics.

8.4.1 SKU management

Next to the implementing the product segmentation, there are also other concepts that have consequences for the supply chain, but their root is found in other parts of the organization. We have seen that uncontrollable stock points are caused by high variability. The cause of this high variability mainly lies in the product portfolio. What we typically see is that each product family has at least 25% products that do not contribute to the turnover of the product family. These products cause variability in the customer demand and thereby have relative high supply chain costs.

Typically the slow-moving, low turnover generating products of a family have relatively high stocks. Besides the fact that it is undesirable for manufacturing and for materials management to have such highly volatile products, we can also argue that having too many products within one family does not result in a good marketing-story. In fact, too many products might lead to a confusing story for the customer. Some clear examples are tools that are available with and without TPS (theft-protection system) and tools that are available with and without PTR (punching through prevention). We recommend that Global Logistics takes the lead in SKU management, because the urge of narrowing down the product portfolio is felt strongest by the supply chain managers.

8.4.2 SBS policy

In the evaluation of the as-is situation has been shown that the factories currently have much 'dead stock'. This insight is gained because the base-stock policy used for evaluating the as-is situation is different than the one used at Hilti. Since the results are quite impressive (it should be possible to remove 50-99% of all the component stock, according to this simulation), we suggest that Hilti starts a project that looks into the possibilities of changing the base-stock policy in the factories. We strongly recommend that in the project a specialist on base-stock policies for manufacturing environments is included.

8.4.3 Coefficient of variance

We suggest based on literature to change the borders for the variability categories as follows (Hopp & Spearman, 2008):

$U: CV < 0.75$
$V: 0.75 \leq CV < 1.33$
$W: CV \geq 1.33$

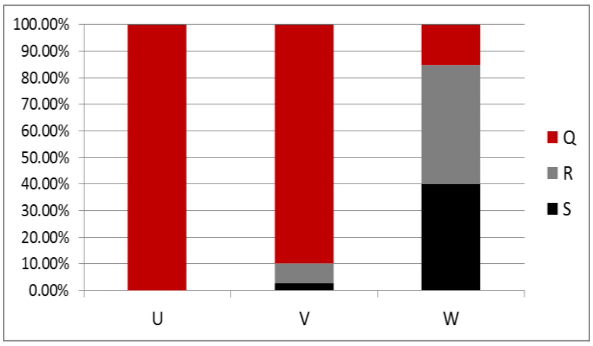


Figure 8-1: The frequency of orders per order variability category, old variability borders.

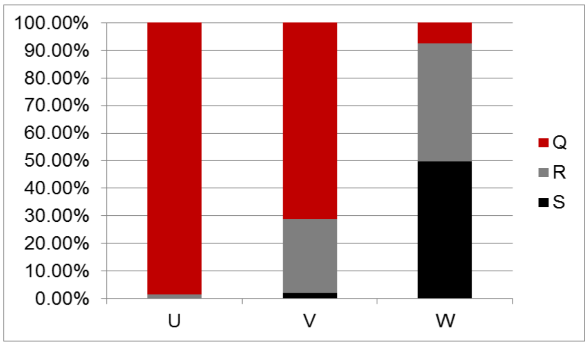


Figure 8-2: The frequency of orders per order variability category, new variability borders.

As stated earlier, the QRS method is a specialization of the UVW method. In Figure 8-1 we show the division of the QRS categories over the UVW categories. If we change the borders as suggested, the division will be as shown in Figure 8-2.

There will be fewer products in category W (a decrease of 12%). All these products shift from category W to category V, and some products move from category V to category U (4.5%). Furthermore, in the figure can be seen that category V contains relatively more products with category R, which is what we would expect based on our earlier statement that the QRS-categorization is a specialization of the UVW-categorization. Changing the borders for this categorization method would mean that the relative products per product segment as indicated on page 29 will change as well.

Furthermore, currently the cluster groups are based on the UVW and QRS methods and are defined with QRS as leading categorization. As an intermediate step to the implementation of the product segmentation, we suggest to change this because we have shown that controllability of a stock point, of which the CV is an indicator, is important in order to regain control of the supply chain. I.e. UVW should be the leading categorization for defining the cluster groups. The cluster groups will then be closely tied to the product segments resulting from this thesis.

Bibliography

Adan, I. J., & van der Wal, J. (1998). Combining make to order and make to stock. *OR Spektrum, 20*, 73-81.

Affonso, R., Marcotte, F., & Grabot, B. (2008). Sales and operations planning: the supply chain pillar. *Production Planning & Control, 19*(2), 132-141.

Aken, J. v., Berends, H., & Bij, H. v. (2007). *Problem solving in organizations: A Methodological Handbook for Business Students.* Cambridge: Cambridge University Press.

Aschenbaum, B., Maltz, A., Ellram, L., & Barratt, M. A. (2009). Organizational alignment and supply chain governance structure. *The International Journal of Logistics Management, 20*(2), 169-186.

Bemelmans, T. (1986). Bedrijfskundig ontwerpen van bestuurlijke informatiesystemen. In P. Cornelis, & J. van Oorschot, *Automatisering met een menselijk gezicht* (pp. 35-49). Deventer: Kluwer.

Bertrand, J., Wortmann, J., & Wijngaard, J. (1998). *Productiebeheersting en material management* (2 ed.). Groningen, the Netherlands: Wolters-Noordhoff bv.

Chang, S.-H., Pai, P.-F., Yuan, K.-J., Wang, B.-C., & Li, R.-K. (2003). Heuristic PAC model for hybrid MTO and MTS production environment. *International Journal of Production Economics, 85*, 347-358.

Corbijn, B., Sjoerdsma, M., & van Wanrooij, M. (2011). *The impact of a lean strategy on the purchasing process.* fulfillment of the course 'strategic sourcing and supply management', Eindhoven.

Croom, S., Romano, P., & Giannakis, M. (2000). Supply chain management: an analytical framework for critical literature review. *European Journal of Purchasing and Supply Management, 6*, 67-83.

de Jong, W. (2010, February) New SCOP Method in ASML Supply Chain: Application of Enhanced Synchronized Base Stock in planning of Supply Chain Planning environment. Eindhoven, the Netherlands: TU/e.

de Kok, A. (2011, February 23). From Lean to Bullwhip. Eindhoven.

de Kok, A. (2012). Controlling business processes: a systematic quantitative approach. Eindhoven, the Netherlands: Eindhoven University of Technology.

Fransoo, J. (2010, August 31). Course: Design of Operations Planning and Control Systems. Eindhoven, the Netherlands.

Fransoo, J., & Kok, A. d. (2003). Planning Supply Chain Oprations: Definition and Comparison of Planning Concepts. In A. d. Kok, & S. Graves, *Handbooks in operations research and management science: Supply chain management: design, coordination and operation* (pp. 597-676). Amsterdam: Elsevier B.V.

Hilti (2009), Global Transport : \\pluto\global-transport\ 96_Manuals_and_Trainings\ 16_GTM_Presentation\ GLT_Presentation_Schenker_30012009.ppt; currently available as Hilti_Tranpsort_year_2010_EN.pptx, slide 14;

Hopp, W., & Spearman, M. (2008). *Factory physics.* Singapore: McGraw-Hill Education.

Ivanov, D. (2010). An adaptive framework for aligning (re)planning decisions on supply chain strategy, design, tactics, and operations. *International Journal of Production Research, 48*(13), 3999-4017.

Jones, G. (2007). *Organizational Theory, Design and Change* (5th Edition ed.). New Jersey: Pearson Education Inc.

Kalantari, M., Rabbani, M., & Ebadian, M. (2011). A decision support system for order acceptance/rejection in hybrid MTS/MTO production systems. *Applied Mathematical Modelling, 35*, 1363-1377.

Kaminsky, P., & Kaya, O. (2009). Combined make-to-order/make-to-stock supply chains. *IIE Transactions, 41*, 103-119.

Koulikoff-Souviron, M., & Harrison, A. (2010, September-October). Evolving HR-practices in a strategic intra-firm supply chain. *Human Resource Management*, 913-938.

Naylor, J. B., Naim, M. M., & Berry, D. (1999). Leagility: Integrating the leand and agile manufacturing paradigms in the total supply chain. *International Journal of Production Economics*, *62*, 107-118.

Oliva, R., & Watson, N. (2011). Cross-functional alignment in supplly chain planning: A case study of sales and operations planning. *Journal of Operations Management, 29*, 434-448.

Perona, M., Saccani, N., & Zanoni, S. (2009, October). Combining make-to-order and make-to-stock inventory policies: an empirical application to a manufacturing SME. *Production Planning and Control, 20*(7), 559-575.

Silver, E., Pyke, D., & Peterson, R. (1998). *Inventory Management and Production Planning and Scheduling.* John Wiley & Sons, Inc.

Soman, C. A., van Donk, D. P., & Gaalman, G. (2004). Combined make-to-order and make-to-stock in a food production system. *International Journal of Production Economics, 90,* 223-235.

Thomas, R. W., Clifford Defee, C., Randall, W. S., & Williams, B. (2011). Assessing the managerial relevance of contemporary supply chain management research. *International Journal of Physical Distribution & Logistics Management, 41*(7), 655-667.

Tsubone, H., Ishikawa, Y., & Yamamoto, H. (2002). Production planning system for a combination of make-to-stock and make-to-order products. *International Journal of Production Research, 40*(18), 4835-4851.

van Wanrooij, M. (2012, April). Redesign of the strategic supply chain planning at Hilti. Eindhoven, the Netherlands: TU/e.

van Weele, A. (2008). *Inkoop in Strategisch Perspectief.* Maarssen: Kluwer bv.

Whybark, D., & Yang, S. (1996). Positioning inventory in distribution systems. *International journal of production economics*(45), pp. 271-278.

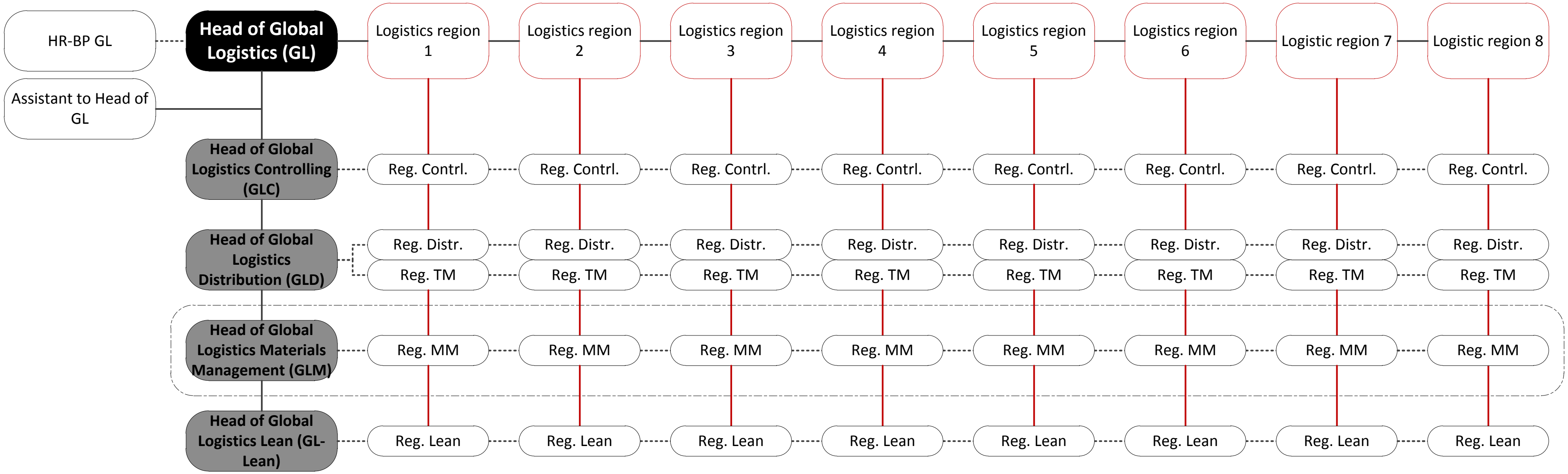
Wikner, J., & Rudberg, M. (2005). Integrating production and engineering perspectives on the customer order decoupling point. *International Journal of Operations and Production Management*, *25*(7), 623-641.

Zhao, X., Huo, B., Selen, W., & Hoi Yan Yeung, J. (2011). The impact of internal integration and relationship commitment on external integration. *Journal of Operations Managment, 29,* 17-32.

List of abbreviations

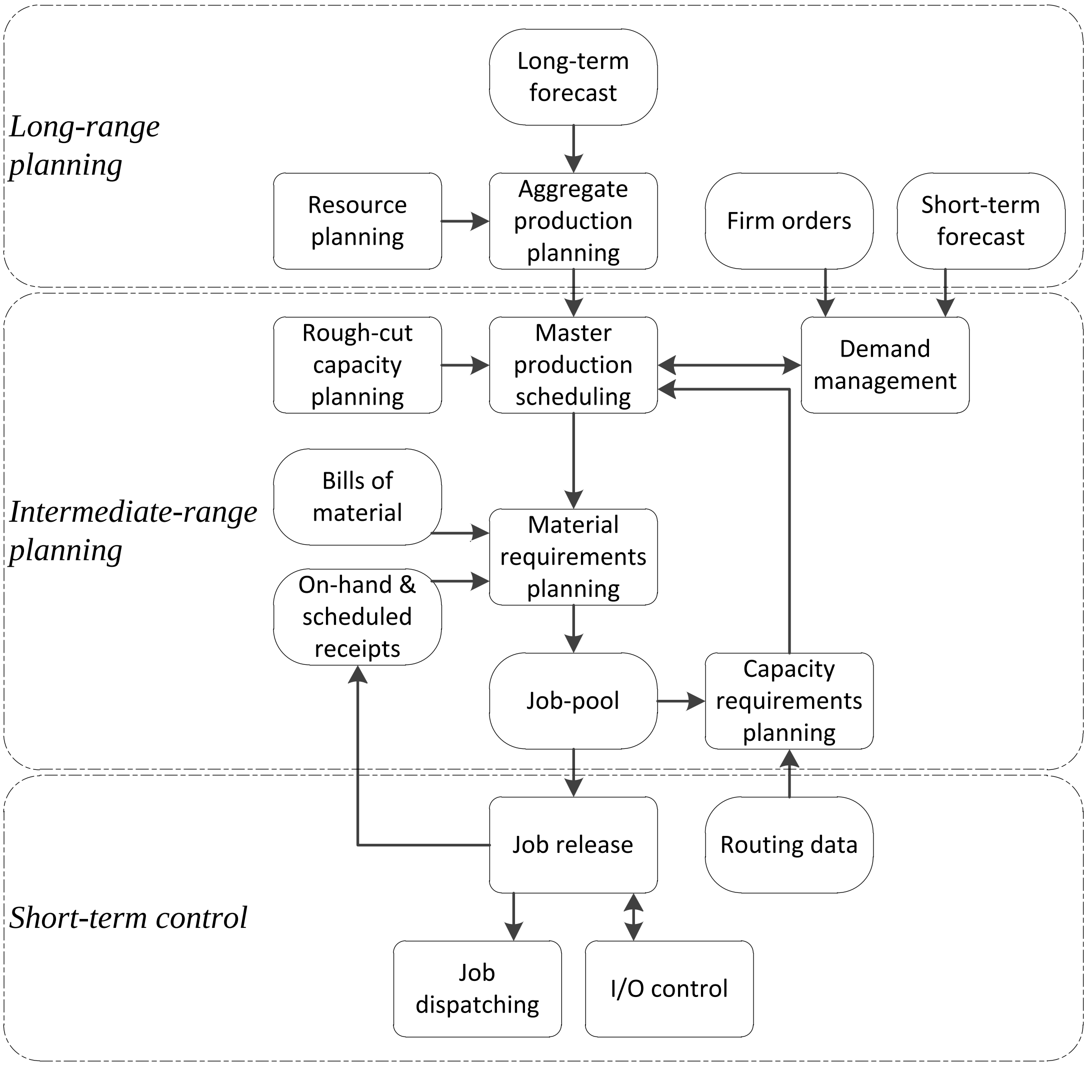
ATO	Assembly-to-order
ATS	Available-to-standard
BTO	Buy-to-order
BU	Business Unit
CODP	Customer Order Decoupling Point
CPOi	Customer-perfect order (internal)
CV	Coefficient of Variance
CW	Central Warehouse
DC	Distribution Center
DP	Decoupling Point
GLM	The department of Global Materials Management
HPM	Human Performance Management
HQ WH	Head Quarter Warehouse
KPI	Key Performance Indicator
LCN	Logistic Center Nendeln
MO	Market Organization
MRP II	Manufacturing resources planning
MTO	Make-to-order
MTS	Make-to-stock
NDC	National Distribution Center
PTR	Punching Through Prevention
PU	Production Unit
RDC	Regional Distribution Center
SCV	Squared Coefficient of Variance
SKU	Stock Keeping Unit
SLA	Service Level Agreement
STS	Ship-to-stock
TPS	Theft-Protection System
WH	Warehouse

A. Appendix to chapter 1

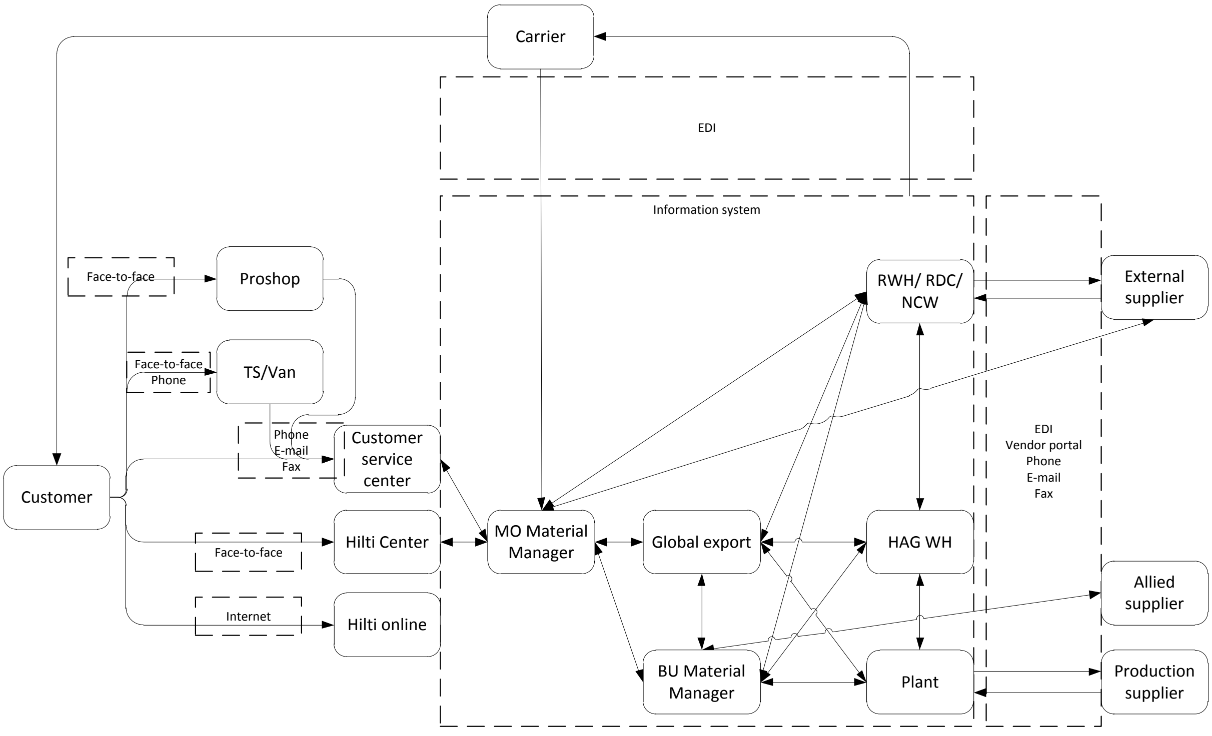


Appendix A- Figure 1: Organization chart of Hilti's logistics organization.

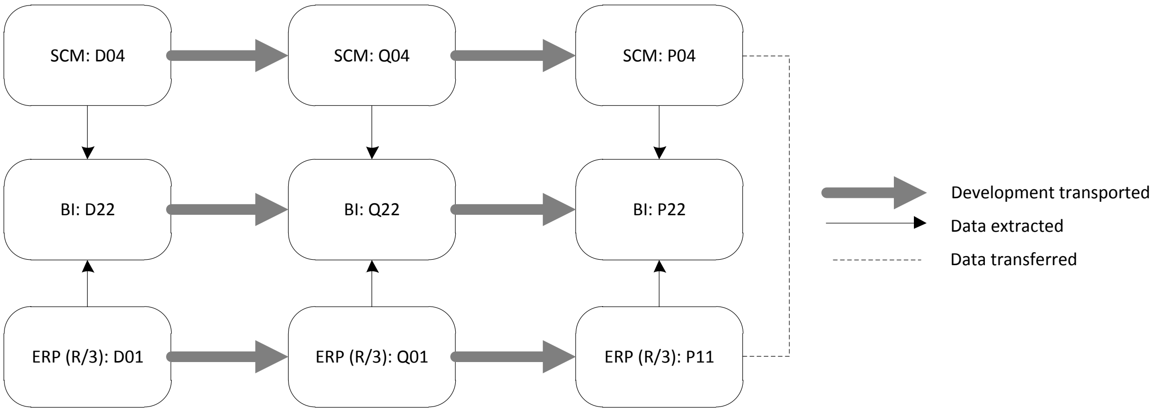
The organization chart pictured in Appendix A- Figure 1 can similarly be drawn up with the same y-axis, but on the x-axis either the factories, or the BUs (supply), or the Traveling Salesmen (TS).



Appendix A- Figure 2: General MRP II hierarchy (Hopp & Spearman, 2008).



Appendix A- Figure 3: Information flow at Hilti, based on the customer order (based on interviews with experts).



Appendix A- Figure 4: Business intelligence (BI) structure.

B. Appendix to chapter 2: theoretical background.

Level	Decisions	Input data	Output data
Strategy	Supply chain goals	Profit Assets Reliability Flexibility	goals
Design	1. Production programme design 2. Cooperation and coordination design 3. Distribution and production design	1. Product variety, Stock keeping units (SKU), Bill of material (BOM), demand, response time, time-to-market 2. Levels of coordination 3. Location data, demand, inventories, process data, movement data	1. which products, what quantity, variety, batches, product availability, technological plan building 2. how is collaborated, what information system(s) 3. how many facilities of what capacities and of what location, suppliers selection, how organize transportation, how to deal with demand uncertainty, how te secure against possible disruptions (e.g. theft)
Planning	1. Distribution and production plans 2. Replenishment plans 3. Shipment plans	1. Demand, costs, capacities, inventory, production volume 2. Demand costs, capacities, inventory, volume 3. Geographic data, transport data	1. Demand forecasts, cycle and safety inventories, capacty utilization, product availability 2. Economic order quantity (EOQ) 3. Routing
Operations	1. Scheduling 2. Available to promise (ATP)/ Capable to promise (CTP) 3. Monitoring 4. Adjustment 5. Deliveries to customers	1. Delivery date, price, delivery place, batch size 2. Customer orders, inventories, capacities, operational and tactical plans 3. Demand, supply, costs, capacities inventory, production volume 4. Deviations, disruptions 5. Delivered products, payments	1. Production scheduling, routing. 2. ATP/CTP response 3. Comparison plan-fact 4. Adaptation steps for operations, for tactics and/or design 5. Performance management

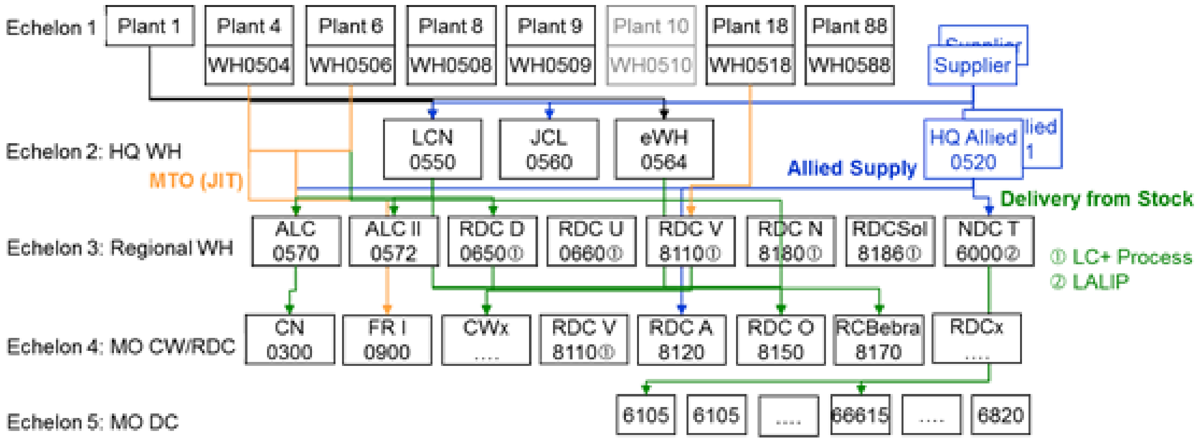
Appendix B- Figure 5: Decisions, input data and output data per hierarchic level, from a metrics point of view (Ivanov, 2010).

Group	Characteristic/ name	Unit of measurement/ description	Variable	Constraint
General data	Plant	All locations where stock can be held for components and/or for finished goods	p	
	Distribution plant	Locations where finished goods are stocked or pass	dp	$dp \in \{p\}$ $dp \neq pp$
	Production plant	Locations where finished goods are manufactured/ assembled	pp	$pp \in \{p\}$ $pp \neq dp$
	Item	Finished good	i	
	Component		c	
	Time	Working days	t	
Item-attributes	Lot size	Amount of items (i) per plant-plant relation (p-p)	$Q_{i,p-p}$	
	Demand	Per item (i), per working day (t), per distribution plant where end-customer demand occurs (cp) ()	$D_{i,cp}(t)$ $\mu_{i,cp}$ $\sigma_{i,cp}$	$cp_i \in \{dp_i\}$
	Distribution plants	Distribution plants where item (i) passes through from the production plant to the end-customer	dp_i	$dp_i \in \{dp\}$
	Distribution network	Relation between all distribution plants of item i	n.a.	
	Target stock levels	Average, per item (i), per plant (p)	$S_{i,p}$	
	Production plant	Plant where item is produced	pp_i	$pp_i \in \{p\}$
Component-attributes	BOM	Relation between all components and item i in production plant pp	n.a.	
	Lead time	Per component (c) in working days (t)	L_c	
	Throughput times	Per component (c) in working days (t)	TT_c	
	Amount	Components (c) per successor (i)	$n_{c,i}$	
	Target stock levels	Relative ratio, Average, per component (c) per successor in scope	$S_{c,i}$	
	Reliability	%	r_c	
Transport & warehousing attributes	Reliability	%	r_i	
	Transport time	From plant to plant	T_{p-p}	
	Handling time goods receive	Per distribution plant (dp)	GR_{dp}	
	Handling time goods issue	Per distribution plant (dp)	GI_{dp}	
Costs	Holding cost	% of item price or component price, per year	h	
	Transport cost	Per kg, per plant-plant relation	c_{p-p}	
	Handling cost	Fixed per distribution plant	c_{dp}	
Capacity	Machines / employees	Number of machines/ employees per component transformation	m_c	
	Transport	Weight	i_w	
	Labour	Number of shifts available to execute a task	s	
	Warehouse	Capacity in m^2 per plant	w_p	

Appendix B- Table 1: Necessary input data for stage 2 of the CODP framework.

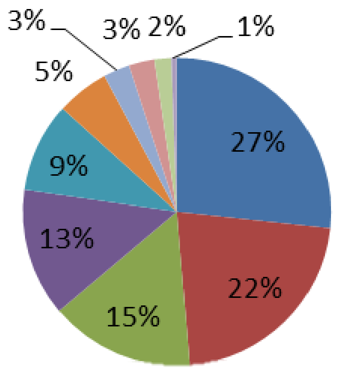
C. Appendix to chapter 3: problem analysis and diagnosis

The deliveries from echelon 1 and echelon 2 are representative for the global demand of an item.

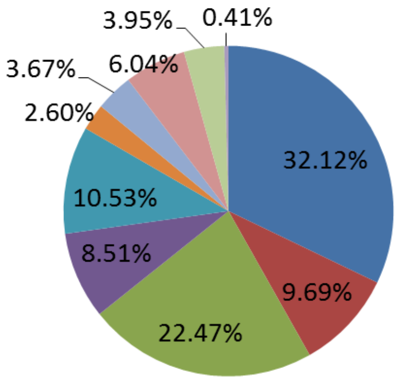


Appendix C- Figure 6: Delivery lines that are used for the calculation of categorization methods UVW and QRS.

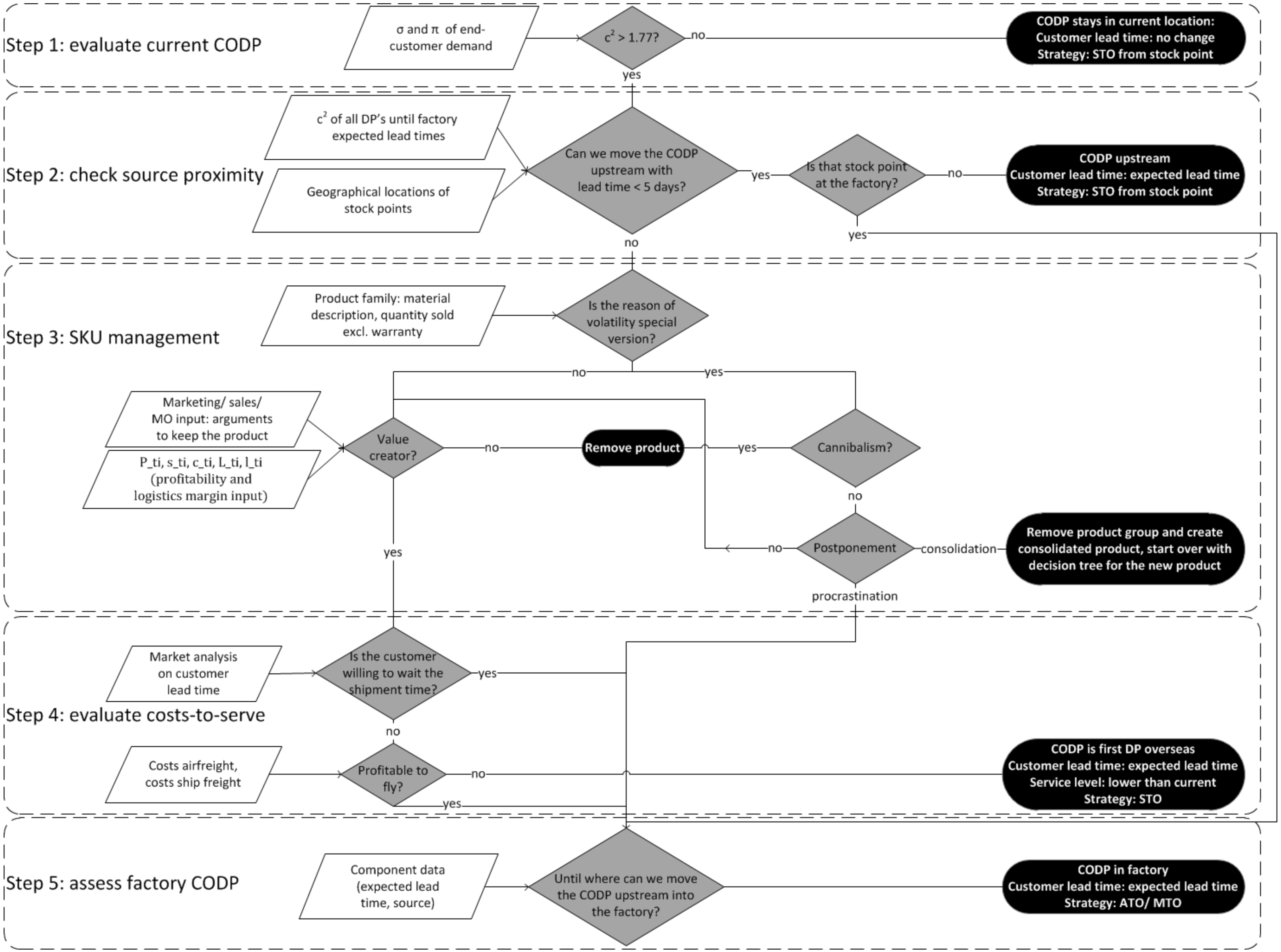
D. Appendix to chapter 4: redesign for Hilti



Appendix D- Figure 7: Number of items per BU in 2011.



Appendix D- Figure 8: Relative sales per BU in 2011.



Appendix D- Figure 9: Decision tree for CODP placement at Hilti.

Decision tree walkthrough per SKU (confidential)

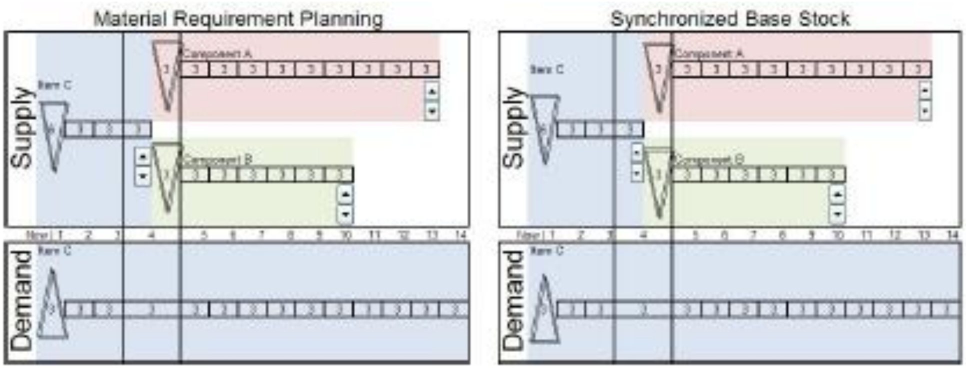
E. Appendix to chapter 5: experimental design (confidential)

F. Appendix to chapter 6: results

Item	ATS	Simulated ready rate
A	100.0 %	99.7%
T,W,R	97.7 %	94.1%
A,V,R	98.4 %	96.1%
A,W,R	95.5 %	98.8%
A,W,S	96.0 %	85.5%
B,V,R	98.7 %	98.7%
B,W,R	95.5 %	97.1%
B,W,S	94.3 %	95.1%
C,W,R	100.0 %	91.0%
C,W,S	66.7 %	93.8%
D,W,R	70.0 %	79.8%
D,W,S	100.0 %	34.9%

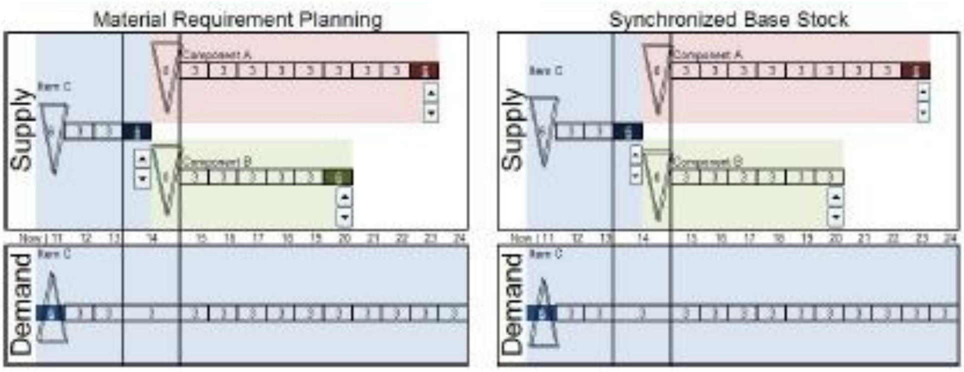
Appendix F- Table 2: Simulated ready rate versus real ATS per SKU (only CWs and DCs).

In his thesis on the application of enhanced synchronized base stock, De Jong (2010) developed an easy-to-understand example that explains the difference between MRP and SBS if unexpected demand occurs: “In this example Components A and B will be assembled into Item C. Demand forecasts show that for the foreseeable future a demand of 3 per period is forecasted. As long as actual demand will be 3 the situation for all periods will look like Appendix F- Figure 10. Item C has a stock of 6; three to supply this period’s demand and three as a buffer. Components A and B also have a buffer stock of three.



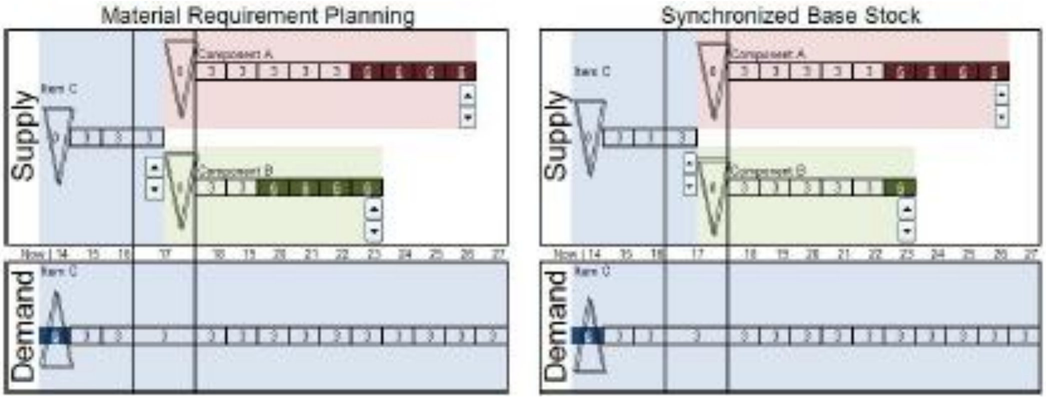
Appendix F- Figure 10: MRP vs. SBS – Normal state.

At some period, period 11 in this case, there is an unexpected high demand of six (Appendix F- Figure 11). This means that the safety buffer of Item C will now be used. For ordering both methods will try to raise the buffer as soon as possible. Due to the synchronization of SBS that method will not order component B higher at this moment. MRP however will order component A and B right when the unexpected demand has occurred.



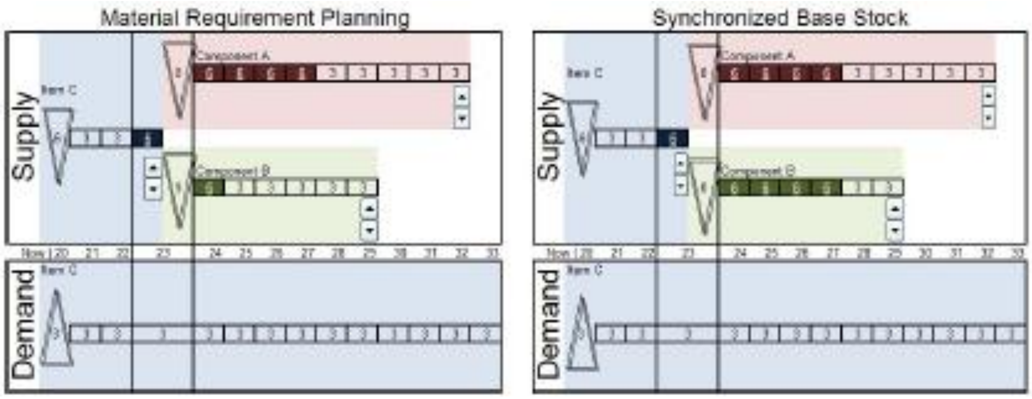
Appendix F- Figure 11: MRP vs. SBS – Unexpected demand occurs, the ordering behavior is different.

After three periods when extra items of component A are in the pipeline at a distance equal to the lead time of component B (Appendix F- Figure 12) SBS will start to order component B. MRP has already ordered B earlier and B is thus in the pipeline.



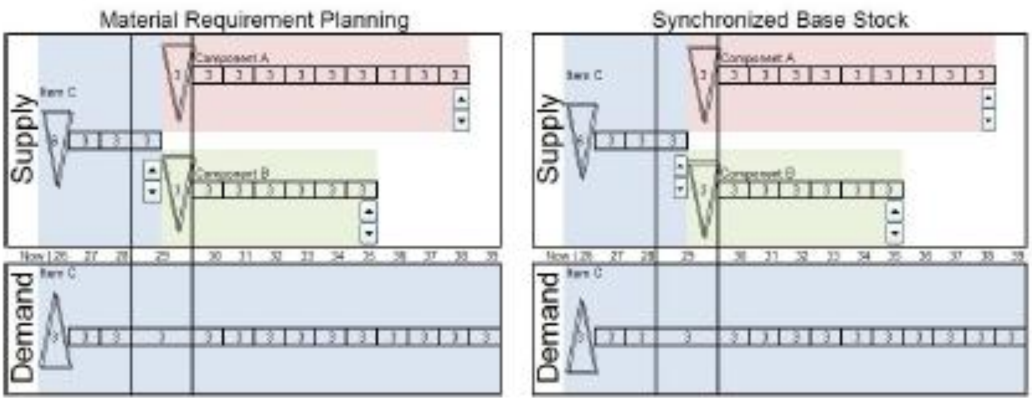
Appendix F- Figure 12: MRP vs. SBS – SBS will start ordering component B.

In Appendix F- Figure 13 it can be seen that although MRP has ordered component B earlier the production of item C will start for both methods at the same time period. The only change is that in the MRP situation extra stock of component B exists.



Appendix F- Figure 13: MRP vs. SBS – Both methods start producing item C.

After some periods the situation (Appendix F- Figure 14) will return to the normal state just like the first picture in this appendix. In a very simple case like this the difference between SBS and MRP due to the synchronization can be easily seen."



Appendix F- Figure 14: MRP vs. SBS – Normal steady state has returned.

G. Appendix to chapter 8: conclusions and recommendations (confidential)