LUT University
School of Engineering Science
Industrial Engineering and Management
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Master's Thesis

# Logistics Network Study for Spare Parts Distribution in APA area

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Supervisor: Professor Janne Huiskonen
Instructor: Anselmi Tuominen

## ABSTRACT

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Supervisor: Professor Janne Huiskonen

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**Keywords:** logistics network study, global distribution, spare parts, APA area, distribution development, strategic network design, service business, supply chain management

The purpose of this thesis was to investigate KONE GSS' spare parts distribution and related structural elements i.e. distribution network, warehouses and transportations. The case company has encountered challenges in its APA area distribution in terms of responsiveness, efficiency and profitability, which are now pursued to be tackled by this study. In this respect, various distribution systems and their structural solutions can serve customers differently. Nevertheless, the costs usually form various trade-offs with the capital and service factors between which, in equilibrium, companies must create a suitable distribution implementation for themselves. The aim of the thesis was to model and explore the case company's current state of distribution, and on this basis try to find out what could be the best way to distribute spare parts in this target area for the future.

In the study, the current state of distribution was initially analyzed and, based on this, various conclusions were made, on the grounds of which in conjunction with the frameworks provided by the theory alternative distribution network solutions were outlined. These design alternatives were then modeled with an Excel-based modeling tool built for the study, which combined optimization with traditional scenario calculation. Subsequently, the outcomes of the alternatives were compared and analyzed from the viewpoints of both service ability and financial and operational performance, while also performing sensitivity analyzing. In addition, the suitability of the alternatives was evaluated from other perspectives such as strategic fit, ease of implementation as well as functionality of the distribution system and risks involved.

As a result of the study, a two-step distribution network development roadmap was introduced, whereby for a start the existing centralized network structure along with its distribution operations would be cleansed and optimized. After this, as the demand of the region reaches its expected growth and when the operations of the frontlines begin to stabilize in the future, it is advised to move to a more straightforward hybrid network structure, which in the long run could increase the operational performance and profitability of spare parts distribution to a whole new level. In comparison to the current state, this recommendation is able to achieve significantly better service ability at lower operational costs and higher capital efficiency, which in many ways will contribute to the underlying maintenance service, while also increasing the value experienced by the end customers.

**TIIVISTELMÄ**

**Tekijä:** Pekka Pellikka

**Työn nimi:** Varaosajakelun logistiikkaverkostotutkimus APA-alueella

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**Hakusanat:** logistiikkaverkostotutkimus, globaali jakelu, varaosat, APA-alue, jakelun kehittäminen, strateginen verkoston suunnittelu, palveluliiketoiminta, toimitusketjun hallinta

Tämän diplomityön tarkoituksena oli tutkia KONE GSS:n varaosajakelua ja tähän liittyviä rakenteellisia tekijöitä eli jakeluverkostoa, varastoja sekä kuljetuksia. Kohdeyrityksessä on kohdattu APA-alueen jakelussa haasteita palvelevuuden, tehokkuuden ja kannattavuuden suhteen, joihin työllä pyritään nyt puuttumaan. Tähän liittyen erilaisilla jakelujärjestelmillä ja näiden rakenneratkaisuilla voidaan palvelle asiakkaita eri tavoin. Näiden osalta kustannukset muodostavat kuitenkin pääoma- ja palvelutekijöiden kanssa tavallisesti erilaisia vastakkainasetteluja, joiden välillä tasapainotellen yritysten on luotava itselleen sopiva jakelutoteutus. Työn tavoitteena olikin mallintaa ja tutkia case yrityksen jakelun nykytilaa, ja tämän pohjalta pyrkiä selvittämään mikä voisi olla paras tapa jaella varaosia kohdealueella tulevaisuudessa.

Työssä analysoitiin ensiksi jakelun nykytila ja tehtiin tämän pohjalta johtopäätöksiä, joiden perusteella yhdistettynä teorian tarjoamiin viitekehyksiin hahmoteltiin erilaisia vaihtoehtoisia jakelurakenneratkaisuja. Nämä rakennevaihtoehdot sitten mallinnettiin työtä varten luodulla Excel-pohjaisella mallinnustyökalulla, joka yhdisti optimoinnin perinteiseen skenaariolaskentaan. Tämän jälkeen vaihtoehtojen tulosantia vertailtiin ja analysoitiin niin palvelukyvyn kuin taloudellisen ja toiminnallisen suorituskyvyn näkökulmista, suorittaen samalla herkkyysanalysointia. Lisäksi vaihtoehtojen sopivuutta arvioitiin myös muista näkökulmista, kuten strateginen vastaavuus, implementoinnin helppous sekä jakelujärjestelmän toiminta ja tähän liittyvät riskit.

Työn lopputulemana päädyttiin kaksivaiheiseen jakeluverkoston kehityssuunnitelmaan, missä aluksi nykyinen keskitetty verkostoratkaisu jakelutoimintoineen siivottaisiin ja optimoitaisiin. Tämän jälkeen, kunhan alueen kysyntä saavuttaa vastaisuudessa odotetun kasvunsa ja kun maayhtiöiden toiminta alkaa vakiintumaan, siirryttäisiin suoraviivaisempaan hybridirakennevaihtoehtoon, jolla on pidemmällä tähtäimellä mahdollista nostaa varaosajakelun toiminnallinen suorituskyky ja kannattavuus uudelle tasolle. Mitä vertailuun tulee, nykytilaan nähden ehdotuksella pystytään saavuttamaan huomattavasti parempi palvelukyky alhaisemmin operatiivisin kustannuksin ja korkeammalla pääomatehokkuudella, joka monin tavoin edesauttaa jakelun taustalla olevaa huoltotoimintaa, kasvattaen samalla loppuasiakkaiden kokemaa arvoa.

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Finally, I would like to express my special thanks to my parents and my sister, whose altruistic support have been very valuable throughout my studies. Thanks also to my friends as well as the closest fellow students of Industrial Engineering and Management, with whom I have shared multiple classes and related group works along with many staggering experiences during my studies.

Lappeenranta, December 2018
Pekka Pellikka

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## ABBREVIATIONS

| | |
|---|---|
| 3PL | Third-party logistics provider |
| ADC | Asian Distribution Center in Singapore (KONE GSS) |
| APA | Asia-Pacific region |
| BIS | Business intelligence system |
| CDC | China Distribution Center in Kunshan (KONE GSS) |
| CV | Coefficient of variation |
| DC | Distribution center |
| EDC | European Distribution Center in Herten (KONE GSS) |
| ERP | Enterprise resource planning software |
| FL | Frontline |
| FTE | Full-time equivalent |
| GDC | Global distribution center |
| GSS | Global spares supply |
| GST | Goods and service tax |
| KEA | Region consisting of Australia and New Zealand |
| KONE GSS | KONE Industrial Oy, Global Spares Supply |
| MES | Major Exporter Scheme |
| MTO | Make-to-order |
| MTS | Make-to-stock |
| NDC | National distribution center |
| NEB | New Equipment Business (KONE GSS) |
| OAT | One-at-a-time (sensitivity analysis method) |
| OEM | Original equipment manufacturer |
| OTIF | On-time and in-full |
| Plant | Aggregated storage location (national) |
| PVD | Product value density |
| RDC | Regional distribution center |
| ROI | Return on investment |
| SEB | Service Equipment Business (KONE GSS) |
| SKU | Stock keeping unit |
| SLoc | Storage location (local) |
| VL06O | Globally distributed active item (KONE GSS) |
| WMS | Warehouse management system |
| XDR | Special Drawing Right (currency code) |

# 1 INTRODUCTION

Today's companies are operating in an ever-changing and evolving globalized business environment where competition has become more and more intensive. In this case, it is important to strive to achieve a competitive advantage from different sources while also cherishing both effectiveness and cost-efficiency. Here, well-designed distribution operations and network structure can help to bring the business to a new level while greatly enhancing customer value creation. This can likewise remarkably reduce operational costs and improve margins. Hence, an increasingly important factor in thriving in the competition and in the quest for business excellence is the quality of the supply chain selection and logistics network design.

Nevertheless, the vast majority of companies' distribution systems still remain unplanned and not frequently re-evaluated as they are just let evolve very much as the company evolves. Most common reasons for this are the lack of understanding about the benefits of a well-working distribution system and that network design studies and related development measures are seen as highly complicated and laborious to conduct. In particularly this is perceived to be problematic with after-sales and spare parts business, where the unique attributes of the industry pose in itself enormous challenges and complexity to both logistics implementation and supply chain management. Often it is needed forward-looking management or a notable change for a company to undertake a large-scale study of this nature. This is unfortunate and often even harmful, as within this industry distribution systems tend to be one of the most significant cornerstones of the business. This is because service providers should be able to provide both high product availability and responsiveness, without sacrificing either cost-effectiveness or capital efficiency.

## 1.1 Background of the study

Similar kinds of problems are also faced in the case company of this study, which is a spare parts department of a multinational industrial equipment manufacturer and service provider. Over the years, the company have expanded their operations, like many others, to global markets in strive for increasing sales and gaining new customers both as part of the parent company's new equipment sales and as self-supplied maintenance services. In recent years, the

Asia-Pacific region (or shorter the APA area) has become one of the company's most significant market areas, which is also seen as an important driver in the future growth.

Now that business have started to reach a more stable state in this area, the company has begun to pay more attention to the effectiveness and efficiency of its operations. In this regard, the company has hints and traces that there would be room for improvement in the APA area's distribution system (some issues may be undervalued, and others overemphasized), but at the moment there is no accurate insight into the current state of affairs. Recently there has likewise emerged an interest in, what could be the most prolific way of implementing the spare parts distribution in the area for the future and what the situation might then look like. These issues and a desire to take the business to a whole new level were the impetuses of this logistics network study, which is also part of a broader logistics development project (Smart Spares Management 2.0).

## 1.2 Objectives and scope

The thesis is focusing on spare parts distribution in the APA area. The research problem to be immersed in and solved during this study is the case company's distribution operations and network structure in this service area with which the company have had performance issues. The catalysts of this particular case have been the company's growing dissatisfaction with the responsiveness and efficiency of the current distribution network, a quandary regarding Asian Distribution Center's (ADC) necessity in this structure as well as recent regional development activities in the distribution of the business-leading KEA area (Australia and New-Zealand), which have aroused interest in the status of this higher-level global network.

To seize this somewhat vast and multilateral research problem, a lot of research questions have been derived, through which the issue is construed and broken into pieces. Given the problem, the main research question to be answered is:

*"Taking into account the characteristics and requirements of the business, what would be the most profitable and operationally efficient way to distribute spares in the APA area for the future?"*

Considering this, a set of both theoretical and empirical questions came up which try to specify the main question. These so-called additional research questions were the following:

Theoretical

1. What is the strategic role of distribution in a global supply chain and why a properly working network structure matters?
2. What does a global distribution network in spare parts context generally look like, and what factors and in which way affect the network structure?
3. What does network design mean and how a logistics network design study can be carried out and, on this basis, develop operations in an empirical research environment?

Empirical

4. What is the current state of distribution like in the case company and what is the role of ADC (Singapore) here?
5. What kinds of strategic network design alternatives could be thought to develop the distribution system and how these would affect the whole?
6. What would be the most viable scenario alternative for the future and what kinds of effects would the recommendation have on daily maintenance work and ultimately on end customers?

## 1.3 Delimitations and outcomes

As was stated the thesis is all about global distribution and related network designing. However, logistics system studies must not be made in isolation without minding the linkages with other processes of the company as well as with other parties in the supply chain. Regarding this, there are several possible ways to describe the intricacy of logistics system designing, but a rather straightforward approach is the one presented by Huiskonen (2001, pp. 127-128). Here the constituting elements of a logistics system are summarized as:

- *Strategy / policies / processes*
- *Network structure*
- *Supply chain relationships*
- *Coordination / control*

, all of which are interrelated with each other and hence should be considered during the design process. For this study, however, we are mainly interested in the network structure and operations of the distribution system in the APA area, and will thus discuss the other aspects only to the extent necessary without going too far into details.

At perspective level, the thesis is concentrated on the distribution side of the supply chain (more specifically physical distribution), which will be examined in the service area by maintaining at the higher-level (*global-regional-national*) without getting too in touched and possibly overwhelmed with the local distribution and its various sides. This matter of study scoping is made in order to keep the project within the boundaries of an academic work. Also considering the aforesaid research problem this will allow the work to be appropriately targeted at the core of the identified problem.

Given these and all the previously mentioned, at the end of the thesis work a logistics network study for spare parts distribution in the APA area will be available, which from the viewpoint of the case company encases:

- ✓ *An overview of the current state of distribution in the area*
- ✓ *Network analysis of selected distribution network what-if scenarios*
- ✓ *A recommendation of the distribution network structure for the future*

## 1.4 Structure of the report

This thesis and hence the report follow a rather basic formula with a little twist to make it more suitable for logistics network design study. Totally there are 11 chapters, which each has their own specific meaning and role in regards the entity. These virtually lead the passage of thoughts and build content bit by bit toward the results and conclusions of the study. As for the structure of the report, this in turn has been built around five main parts, which are depicted in Table 1 below. As can be seen:

*I.* *The first part* is the so-called theoretical part or literature review where different ideas from literature are gathered and based on these, the meaning and role of distribution and related network structures in a supply chain are elucidated as well as generic building blocks and guidelines for supply chain segmentation and network design in a global context are composed. During this, the spare parts industry is alike considered by drawing ideas about characteristic of spare parts, how to handle their logistics operations and what could be a suitable distribution network structure for them. The theoretical part is concluded with generic steps on how to conduct a strategic network design study and related analyses.

*II.* *In the second part,* the research process and methods used in this work to study the distribution network are presented. To conduct the research, a theory-based problem-solving and modeling study was carried out. The study itself was very multifaceted and practical, and involved building a modeling tool based on theory. This tool was then capitalized to model and test different scenario alternatives drawn from literature findings, and eventually solve the spare parts distribution related logistics problem.

*III.* *The third part* is the current state analysis part where first the case company and its business context are briefly presented, and after this the look is moved to describing and modeling the current state. The idea here is to analyze the case company's present state of operations and functioning of the distribution network in the area while raising some development ideas for the upcoming what-if scenario analysis.

*IV.* *In the fourth part,* the what-if scenario alternatives developed to test different distribution structures are covered. Here each scenario is first described, and then their results as well as comparison to the current state is briefly presented. After this there is a more pervasive scenario comparison and analysis, where the scenario alternatives are compared against each other and analyzed in terms of network design decision variables drawn from literature. In addition to this, the results of the conducted sensitivity analyses will also be compared and analyzed. These in turn raise understanding about the robustness of the scenarios and hint what would be a potentially good solution for the future.

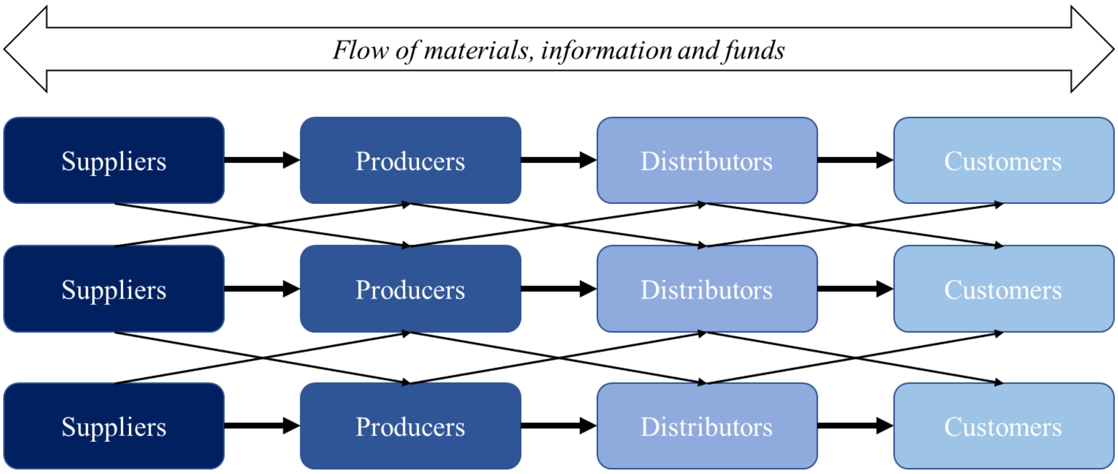
*V.* *In the fifth and final part,* the findings and results from the what-if scenario analysis are shortly discussed from various aspects and based on this a development roadmap for the future is delineated. Here the impacts of the recommendation on maintenance service are also deliberated from the viewpoints of both daily maintenance work and end customer satisfaction. The part is concluded with encountered study constraints and possible additional research topics for next steps for the future.

**Table 1. Structure and contents of the report**

| *Chapter* | **Title** | **Contents briefly** | |
|---|---|---|---|
| *1* | INTRODUCTION | • The background of the study along with the definition of objectives, scoping and initial outcomes are presented. In addition to these, the structure of the report is briefly described in order to give a hint what is coming. | |
| *2* | GLOBAL SUPPLY CHAIN MANAGEMENT AND DISTRIBUTION | • A literature view on global supply chain management and distribution's role and meaning in this are presented, which strive to serve as a theoretical introduction to the case company's operations and business. In addition to this, also the benefits of a properly working distribution network are reviewed to give insights why network modeling matters in the first place. | **Part I** |
| *3* | DISTRIBUTION SYSTEM AND NETWORK STRUCTURES | • The literature view is continued with the distribution system and related network structures. Here building blocks of a global distribution system, generic design trade-offs and related network structure archetypes are introduced. Also, the costs of distribution and factors influencing distribution network structure are reviewed. The chapter is concluded with guidelines and a framework for supply chain segmentation and network design, which will act as a theoretical premise for the upcoming what-if scenario development. | **Part I** |
| *4* | SPARE PARTS BUSINESS FROM THE VIEWPOINT OF SUPPLY CHAIN MANAGEMENT | • The literature view is reinforced with insights in spare parts business, its special features and the challenges that this pose to supply chain management. In addition to this, generic ideas about global spare parts distribution and network structures used in this are also presented in order to complement the previously delineated design premise with more hands-on views. | **Part I** |
| *5* | CONDUCTING STRATEGIC NETWORK DESIGN AND ANALYSIS | • The literature view is concluded with insights on network design and analysis as a research method and how to properly conduct a strategic network design study. Here, for example, the steps to complete a network design study, generic data needs, advises to data processing as well as needed forms of analyses are covered. | **Part I** |
| *6* | RESEARCH PROCESS AND METHODOLOGY | • Description of the research process and methods used to conduct the logistics network design study is provided in a step by step form. In addition to this, the data collection process along with the modeling tool built for the study and its inner life are also presented in a detailed manner to make it possible to replicate the research. The chapter is concluded with the delineation of the assumptions and generalizations made during the study. | **Part II** |
| *7* | CURRENT STATE ANALYSIS IN THE CASE COMPANY | • The case company and its business context are first briefly presented. After this the current state of distribution in the APA area is described, modeled and analyzed. As a conclusion, the major findings from the current state are composed into a summarizing table with development ideas for the upcoming what-if scenario analysis. | **Part III** |
| *8* | WHAT-IF SCENARIO ANALYSIS IN THE CASE COMPANY | • A declaration of the conducted what-if scenario analysis and its results is provided. In this, each scenario alternative developed to test different network structures is conversed on and their results in terms of distribution key figures are briefly presented. In addition to this, the scenarios and their results are also compared with the current state of distribution to reify the progression as the network structure is varied. | **Part IV** |
| *9* | COMPARISON AND ANALYSIS OF THE WHAT-IF SCENARIOS | • A presentation of the done scenario comparison and analysis is provided, where the previously described what-if scenario alternatives are compared against each other and analyzed in terms of various network design decision variables drawn from literature. In addition to this, the results of the performed future-oriented sensitivity analyses are also presented and analyzed. As a result of these, it is possible to point out how the scenarios are coping in the light of numbers and what are the relative "balances of power" both now and in the future. | **Part IV** |
| *10* | DISCUSSION AND CONCLUSIONS | • Major findings and results from the what-if scenario analysis are revised and evaluated against the company's strategy, operational environment as well as other practical considerations to form a recommendation for the future. After this, the effects of the recommendation on maintenance service are pondered. The chapter is concluded with a deliberation on the encountered constraints during the study and how these have affected the results. In addition to this, suggestions on further actions are also discussed. | **Part V** |
| *11* | SUMMARY | • The contents and results of the study are summarized in a concise manner. | |

# 2 GLOBAL SUPPLY CHAIN MANAGEMENT AND DISTRIBUTION

In general, supply chains can be defined as dynamic networks constituting of organizations, functions, resources and information involved in moving products and services from sources of supply to end customers hence striving to fulfill customer requirements. Supply chains connect producers and their suppliers to distribution organizations and customers, and typically involve a variety of stages which are connected through the flow of materials, information and funds. The flows often occur in both directions and are coordinated and managed in cooperation among the parties involved. With each organization, the supply chain includes all functions involved in receiving and fulfilling a customer request. These usually include but are not limited to activities like product development, procurement, manufacturing, sales and marketing, distribution, finance and customer service. (Chopra & Meindl 2013, pp. 13-14) Figure 1 below visualizes in a simple network form a typical supply chain along with the various flows inheriting in this.




(Sanders 2012, pp. 5)

**Figure 1. Illustration of a typical supply chain network and different flows within it**

Managing supply chains and distribution operations in these is an important part of business and competition, as they affect directly to costs and customer value. This is, though, getting ever-hardening as companies are globalizing and spreading their networks all around the world. Next, supply chain management in global business environment, the role of distribution in a supply chain as well as how a properly working distribution network can support business are discussed to provide insights of what to look for in distribution related logistics network studies and why network modeling even matters in the first place. This also strives to serve as a theoretical introduction to the case company's operation and its role in the service chain in question.

## 2.1 Supply chain management in global business environment

As was previously stated, supply chain management is an essential part of successful business and competition, but what does supply chain management exactly stand for and what it strives to do? There is a wide variety of different definitions for the term supply chain management, but Simchi-Levi et al. (2004, pp. 2) have defined this quite successfully as follows:

*"Supply chain management is a set of approaches used to efficiently integrate suppliers, manufacturers, warehouses and stores so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time in order to minimize systemwide costs while satisfying service level requirements."*

This definition encases several observations about the nature of supply chain and operations management. Firstly, supply chain management takes into account every facility that has impact on costs and plays some role in making the product conform to customer requirements. Secondly, the objective of supply chain management is to be both efficient and cost-effective across the entire system in order to minimize the total systemwide costs. Thirdly, because supply chain management revolves around the efficient integration of suppliers, manufacturers, warehouses and stores, it is comprising companies' activities at many levels from the strategic level through the tactical to the operational level. (Simchi-Levi et al. 2004, pp. 2-3)

So, effective supply chain management involves the management of supply chain assets and both material and information flows in it to maximize the total supply chain value. The value that a supply chain generates is the difference between the value of the offering to the customer and the costs that the supply chain incurs in fulfilling the customer's request, or in other form:

$$Supply\ Chain\ Value = Customer\ Value - Supply\ Chain\ Costs$$

As has already been emphasized, the primary purpose of any supply chain is to satisfy customer needs and, in this process, try to generate profit for itself. Supply chains' success is often measured in terms of supply chain profitability, which comes as a by-product of this above-mentioned value generation and is stated as *the difference between revenue generated from the customer and the overall cost across the supply chain*. The higher the profitability, the more successful the supply chain tends to be. (Chopra & Meindl 2013, pp. 14-15) Of course, this totality is also affected by the overall commitment of capital to the system and its utilization.

One area of significant change in recent years has been the rapid growth of globalization and international trade. Nowadays most companies serve multiple global markets, with products sourced and produced across many continents. Once again, the need is to plan and manage supply chains as complete and integrated systems. However, when operating in a global landscape supply chain networks become far more contingent, extensive and in every way complex. This complexity provides some fundamental implications for logistics operations, which tend to make the supply chain management challenging. These include:

- *Extended supply lead times*
- *Production postponement due to the needed local added value*
- *Extended and unreliable transit times*
- *Need for the use of multiple freight transportation options*
- *More complicated warehouse and node management*
- *Greater need for visibility in the supply chain*

As can be derived from this, in global context supply chains tend to see increased lead times and hence risen inventory levels because of the distances involved and the complexity of logistics. It is perhaps clear from this that there is an obvious conflict between globalization and the move to the Lean-like just-in-time operating model that is being sought by many companies. In companies moving to this Lean philosophy there is a desire to reduce lead times and to eliminate unnecessary stock and waste within their processes. For those companies trying to achieve both goals, there will be clear challenges in terms of logistics and supply chain management. (Rushton et al. 2010, pp. 23, Sanders 2012, pp. 345-347)

## 2.2 The role of distribution in a supply chain

Physical distribution is responsible for delivering products to customers on time and at minimum cost. In general distribution refers to the methods and means by which items are moved and stored in a supply chain as they make their way from the supply-side to the demand-side. Distribution is often a key driver for companies' success as it affects directly on both supply chain costs and the customer value. It would be no exaggeration to state that many of the world's most profitable companies have built their business success around outstanding distribution design and operation. (Arnold et al. 2011, pp. 285; Chopra & Meindl 2013, pp. 80; Rushton et al. 2010, pp. 50)

To be able to develop and introduce an effective distribution system it is first necessary to understand what utility values distribution contributes to and what roles it plays in supply chains. The bases for this discussion are the customers in the supply chain. As described earlier, activities in a supply chain are aimed at satisfying customers' varied needs by supplying different kinds of goods and services. In order to succeed in this, following utilities should be provided by the supply chain:

- Form utility, which denotes the added value created through the value refinement of input materials to end products
- Place utility, which denotes the added value created through making products available for customers at the right place
- Time utility, which denotes the added value created through making products available for customers at the right time
- Ownership utility, which denotes the added value created when the ownership rights of a product are transferred to a customer

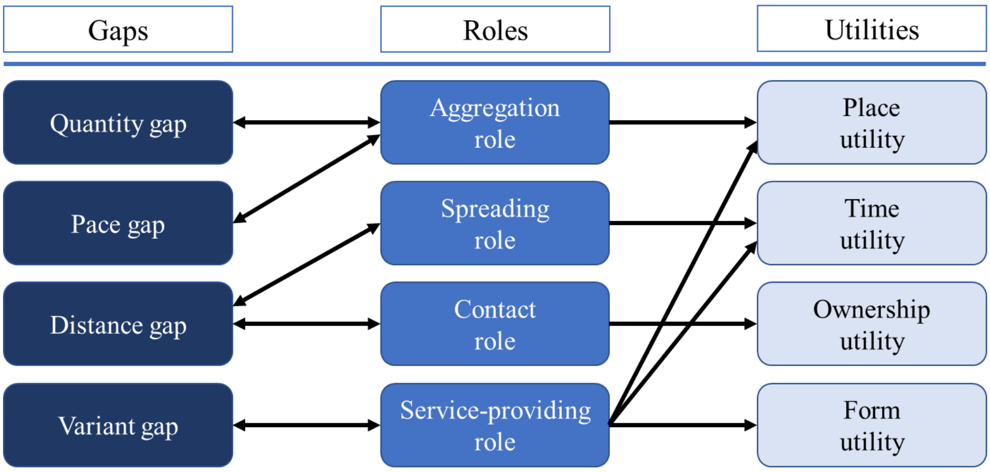
Of these utilities, companies' sales and marketing units traditionally account for the ownership utility, their production units for the form utility and the distribution units for both the place and the time utility. However, this division can be executed in several different ways among different units in a company or even between various parties in the supply chain. (Jonsson 2008, pp. 212-213)

Another fundamental issue in the planning of distribution systems is how to bridge the gaps of *"quantity, consuming pace, distance* and *product variety"*, which exist between suppliers and end consumers. Bridging these gaps is the prerequisite for a supply chain being able to produce the previously mentioned utilities for customers. Distribution units traditionally account for these gaps and regarding distribution functions it is possible to identify some fundamental roles for the bridging. These roles are:

- The aggregation role, which reflects that a distribution organization with a stocking function aggregates supply with demand, and dispatches deliveries equivalent to each customers' individual needs
- The spreading role, which reflects that a distribution organization designs it warehouse network in a way that it can be close to each market and deliver products with sufficient delivery times to fulfill customer needs
- The contact role, which reflects that a distribution organization takes care of direct customer service by having units for technical, application and other types of customer related service and support
- The service-providing role, which reflects that a distribution organization carries out order-specific product configuration to be able to provide more specific offerings for customer needs, while striving to avoid transporting a vast variety of different end products in small quantities

To the extent that the gaps are manageable through distribution activities, different types of intermediaries (agents, wholesalers, transportation companies and warehousers) can and often also should be used to achieve a more cost-effective bridging. (Jonsson 2008, pp. 213-217)

Designing distribution operations and structures are to a large extent concerned with the utilities to be provided by the distribution unit along with the question of how to arrange the needed roles to bridge the gaps existing between the supply-side and the demand-side. Figure 2 below tries to reify this by illustrating the aforesaid gaps, roles and utilities as well as the underlying links and relationships between them.




(adapted from Jonsson 2008, pp. 215)

**Figure 2. Illustration of distribution related gaps, roles and utilities which constitute the basis for distribution activities**

As was stated, the generic purpose of distribution is bringing products available to markets. Given this, the underlying distribution system objectives will understandably differ from one company to another. However, it is possible to define some set points that are likely to be relevant and should be considered during the distribution planning process in order to ensure that an adequate system architecture is constructed. These are:

1. *To make products readily available to the consumers at which they are aimed*
2. *To achieve the required level of service*
3. *To enhance the prospect of sales being made*
4. *To minimize logistics and total costs*
5. *To achieve cooperation with regard to any relevant distribution factors*
6. *To provide fast and accurate feedback information*

To reach these, all activities involved in the storing and movement of products must be organized into an integrated system. Management should also treat the system as a whole and understand the underlying relationships among different distribution activities. (Arnold et al. 2011, pp. 285-286; Rushton et al. 2010, pp. 55-56)

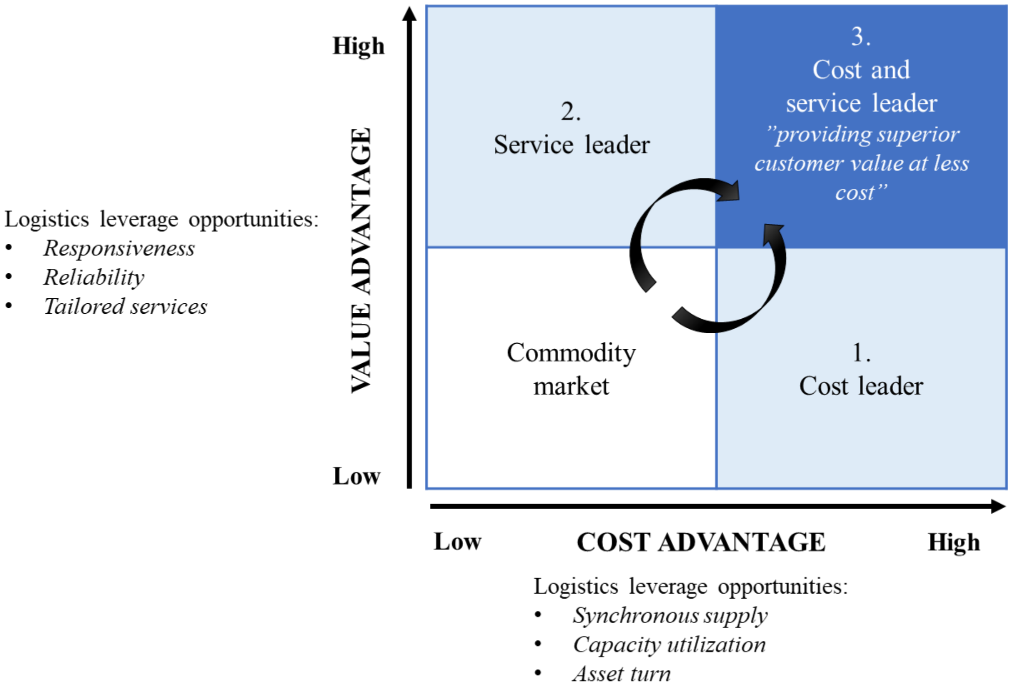
## 2.3 How a properly working distribution network can support business

A properly working distribution system can be used to achieve a variety of logistic objectives ranging from a low cost to high responsiveness. In addition to this, functional distribution operations are essential for products to be able to consistently flow from the point of origin to the end users, regardless of the industry served. Thus, a well-designed distribution network can significantly increase the overall supply chain value by enhancing the customer experience while also reducing operating costs and improving capital efficiency at the same time. On the other hand, an inappropriate network design can have a significant negative impact on the success of companies, as has been evident in the bankruptcies of former Fortune 500 companies like Blockbuster, Borders and Toys ‘R’ Us. Therefore, companies should be fully aware of the meaning and impacts of distribution network design on business. In the following sub sections, these issues are discussed with the emphasis on how a properly working distribution network can provide competitive advantage as well as enhance financial performance. (Chopra & Meindl 2013, pp. 81; Pickett 2013, pp. 30)

### 2.3.1 Impacts on competitive advantage

Seeking a sustainable and defensible competitive advantage is a never-ending puzzle of every company. Given the intensified competitive pressure of international trade, the ever-hardening realities of the market as well as the changing customer preferences it is no longer possible to assume that products would sell themselves. Neither is it advisable to think that the success of today will carry into tomorrow. Therefore, in order to stay in the competition, companies must continuously seek ways to endure their superiority over competitors. An efficiently working and effective distribution network can play a major role in this. (Christopher 2011, pp. 4; Sanders 2012, pp. 346)

When it comes to competitive advantage, an off-repeated marketing fact is that unless the products that the company is offering can be distinguished from its competitors, there is a strong likelihood that customers will view them as “commodities” and the sale will go to the cheapest supplier. Therefore, companies in any industry strive to find superiority over competitors at any cost. In general, the possibilities are either to be the low-cost producer or the supplier providing products with the greatest perceived value. (Christopher 2011, pp. 4, 6) These strategic paths, along with the logistics leverage opportunities in capturing competitive advantage are delineated in a matrix form in Figure 3 below.




(adapted from Christopher 2011, pp. 7-9)

**Figure 3. Gaining competitive advantage through logistics**

As can be seen:

1. The first and the most obvious way out of this "commodity quadrant" of the matrix is through *cost advantage*. Traditionally, it has been argued that the main route to cost leadership is through the achievement of greater manufacturing and sales volumes. However, this blind pursuit of the economies of scale through ever-increasing volumes may not always lead to the required cost reductions to be the lowest cost operator in the industry. The reason is that in many industries, logistics costs nowadays represent a such significant proportion of total costs that it is only possible to make major cost reductions through fundamentally re-engineered logistics operations and network. Thus, it can be stated that it is increasingly through better logistics and network design that efficiency and productivity can be achieved leading to substantially reduced operating costs as well as to cost advantage. (Christopher 2011, pp. 5, 8)

2. The second way out of this "commodity quadrant" of the matrix is to *seek a strategy of differentiation through value advantage*. It has long been an axiom in marketing that "customers do not buy products, they buy benefits". Hence it is important to seek ways to leverage the value of offerings to distinguish them from the competitors. Traditionally adding specific value through product differentiation has been one of the main means of achieving a sustainable advantage in the market. However, recently there has been an increased convergence of characteristics within different products, which has led to that it is no longer possible to effectively compete just on the basis of product differences. Many companies have responded to this by turning their attention to services, which has become an equally powerful as a means of gaining additional value. By offering greater responsiveness and reliability that enables customers to do a better job of serving their own clientele can offer the much-needed superiority over competitors. Here a properly working distribution network along with efficient logistics operations again plays a vital role. (Christopher 2011, pp. 6, 8)
3. The third and the most ultimate way out of this "commodity quadrant" of the matrix is to *try to capture both the cost advantage and the value advantage*. It has been argued that in the markets of the future the leading organizations would be those that have sought and achieved this twin peaks of excellence. Obviously, this sector is of remarkable strength and it will be extremely difficult for competitors to attack against a company occupying the position. However, in order to get here, companies need to find a way to plan and execute their logistics operations in such a manner that customers can be served at higher levels and yet at lower cost. (Christopher 2011, pp. 8-9)

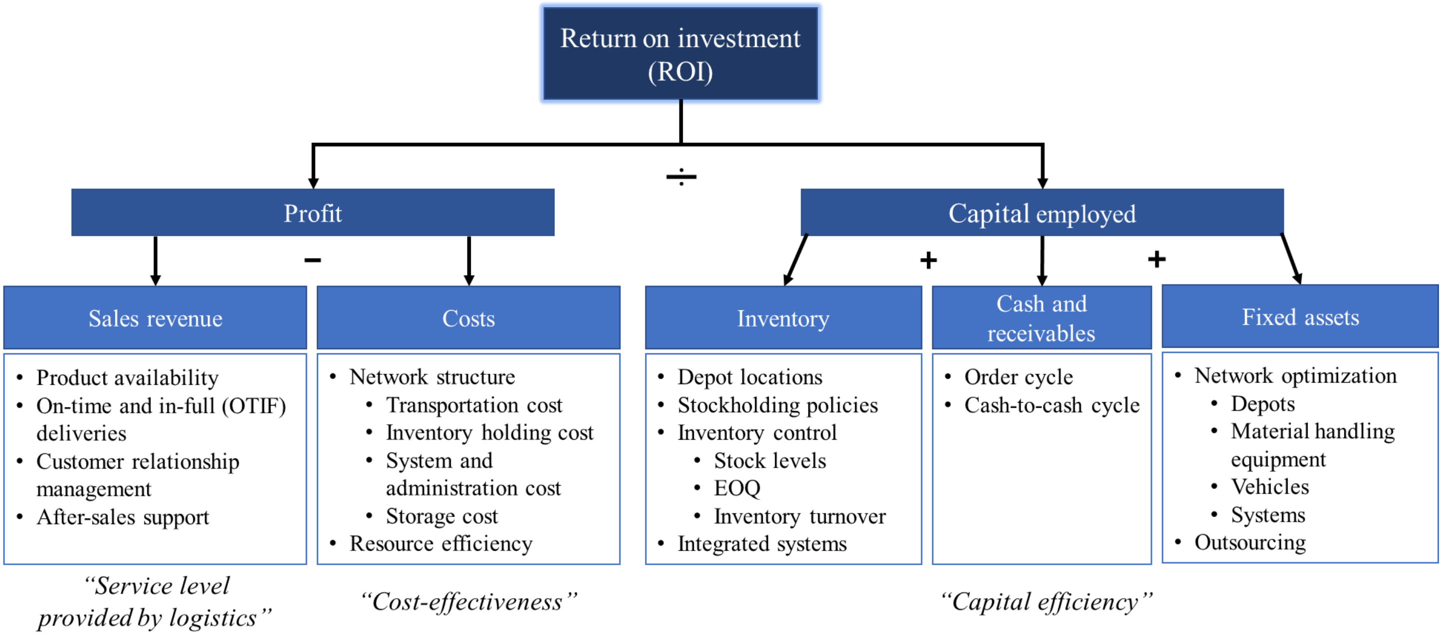
The way a company aligns itself against its competitors and what direction it will finally choose depends, though, on the market as well as the competitive strategy, which defines the targeted customer segments along with their specific customer needs that the company aims to satisfy through its products and services, while taking also into account the competitors. To capture competitive advantage and thrive in the market, companies obviously need to be able to forward these things to the network level by developing a supply chain strategy that is well aligned with the competitive strategy. This in turn refers to achieving a strategic fit between competitive and supply chain strategy, which tends to be of the fundamental drivers in success. (Chopra &

Meindl 2013, pp. 31-33) This notion will be further elaborated in the following chapters from the viewpoint of distribution network design.

### 2.3.2 Impacts on financial performance

Logistics, especially distribution that operates at the customer interface, have significant impacts on companies' business and economics, and therefore a well performing distribution network can offer remarkable opportunities to boost financial performance. There are a variety of different ways in which logistics can have either a positive or a negative impact on financial performance. These can be quite well elucidated through the return of investment (ROI), which tends to be the key measure of financial success for many companies. (Rushton et al. 2010, pp. 21)

The return on investment is the ratio between the net profit (sales revenue less costs) and the capital employed into the business, which in general measures the profitability of business. In Figure 4, this is further broken down to the main elements which constitutes the indicator, along with the means through which logistics influences these. (Rushton et al. 2010, pp. 21)




(adapted from Rushton et al. 2010, pp. 22)

**Figure 4. Influence of logistics on companies' financial performance**

As can be interpreted from the figure, for improved financial performance the ratio should be shifted by *increasing profits* and *reducing capital employed*. In general, profits can be enhanced through increased sales revenue and decreased costs. When considering distribution, sales tend to benefit from the provision of high and consistent service level by logistics. Here the major influencers are the product availability and achievement of the on-time and in-full (OTIF) deliveries. Also significant for customer retention is efficient customer relationship management along with after-sales support. On the other hand, costs can also be reduced through cost-effective logistics operations. This might be achieved in several ways, but the most significant factor driving total logistics cost is in fact network structure. Also crucial is the planning and coordination of operations along with the efficient use of resources. (Rushton et al. 2010, pp. 21-22)

When it comes to the amount of capital employed, this is likewise under the influence of logistics. In general, total assets consist of inventories, fixed assets and cash and receivables, which all can be reduced through effective logistics planning and network design. For example, inventories and their stock levels can be influenced with depot locations, stockholding policies, inventory control, replenishment procedures and integrated systems, among other things. In the same way, the fixed assets found in the logistics network along with the number, size and extent of their usage can be affected with effective logistics planning and network optimization. There may likewise be opportunities to outsource some or all of these operations to third-party service providers, which tend to have even more significant effect on reducing both fixed assets and logistics costs. Finally, there remains cash and receivables. These are alike highly dependent on logistics, in particularly order and cash-to-cash cycle processes, and are therefore under the influence of logistics planning. (Rushton et al. 2010, pp. 22)

As can be seen, a well-designed distribution network can significantly improve capital efficiency, reduce operating costs as well as enhance the customer experience. Therefore, companies should pay attention on their logistics operations and network design to capture these financial benefits.

# 3 DISTRIBUTION SYSTEM AND NETWORK STRUCTURES

The previous chapter introduced the concept of distribution and discussed its meaning and role in a supply chain. It was pointed out that distribution strives to bring together the flows of material and information between the supply-side and the demand-side in a supply chain in order to satisfy customer requirements and needs. To reach this, all activities involved in the storing and movement of products must be organized into an integrated system. Management should also understand the relationships among these activities because what happens to one activity tend to influence on other activities and the system as a whole. (Arnold et al. 2011, pp. 285-286; Jonsson 2008, pp. 218)

The objective of distribution management is to design and operate the distribution system in a way that it attains the required level of customer service and does so at the least possible cost. The network construction that should be used in this, depends however on the situation and varies by the nature of the business, the market and its characteristics along with the products being distributed. Hence, management must discover and determine the distribution network structure and operations within it that is the most suitable given the firm's business environment combined with its objectives and strategy. (Arnold et al. 2011, pp. 285-286; Sanders 2012, pp. 111) In the coming chapter, this concept of distribution system and its structural and operational elements are outlined. The chapter starts with the basic building blocks of a distribution network, and proceeds through strategic trade-offs and structural archetypes to costs related to the distribution system. The chapter ends with an illustration of factors affecting distribution network design and a framework with which network design related segmentation and selection can be done.

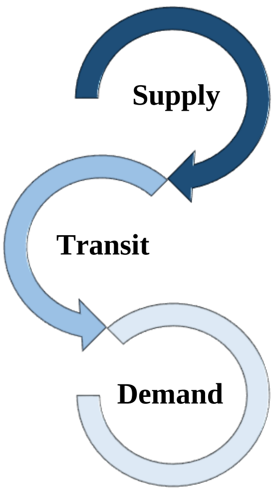
## 3.1 Building blocks of a global distribution network

To understand how to optimally construct a distribution network, it is first important to discuss what are the basic building blocks of this and why they are needed? As was stated in the previous introductory paragraph, distribution networks can vary greatly in terms of structure and operations execution. However, what is common to every distribution system is that they are constructed of the same basic blocks which are then combined in a different way to provide a solution that is right for one's distribution needs. The generic building blocks are *inventories*, *transportation* and *third-party logistics providers*. Next these are discussed more closely with a glance in the global field of action.

### 3.1.1 Inventories

The first building block of a global distribution network is inventories. Inventories, also referred as stocks or warehouses, represent both facilities in a supply chain where companies store their goods and meeting places where products pass through from one vehicle to another (Watson et al. 2013, pp. 7). Inventories generally exist in the supply chain because of a mismatch between supply and demand, which they are trying to balance by storing and having the products readily available when customers need them (Chopra & Meindl 2013, pp. 59). Inventories usually come in various types and sizes and may be owned and operated by either the company itself or intermediaries such as third-party logistics (3PL) providers (Arnold et al. 2011, pp. 296).

When taking into account the previously presented total logistics concept of supply chains, inventories can also be seen as strategic leverages to gain both effectiveness and efficiency in a distribution network. Hence, beyond this general reason for the existence of inventories, a slew of other incentives for holding inventories in a distribution network can also be found. These are summarized in the following Figure 5.




- *To help buffer lead times.*
- *To be able to exploit the economies of scale during production and sourcing (by enabling lot sizes and economic order quantites).*

- *To be able to exploit the economies of scale during transportation by allowing full vehicle loads to be used.*
- *To enable trade-offs within the transportation system by allowing different modes to be used.*

- *To be able to consolidate products coming from various sources and in this way facilitate order assembly.*
- *To help provide excellent customer service by positioning goods close to markets so that customers can be served both more effectively and efficiently.*
- *To enable managing seasonal spikes of demand more economically.*

(Rushton et al. 2010, pp. 118-119; Watson et al. 2013, pp. 118-119)

**Figure 5. Strategic incentives for holding inventories in a distribution network**

To be able to match up the list of reasons with proper types of facilities, it is also important to be aware of the alternative types of inventories. (Watson et al. 2013, pp. 8) Generally there may be many kinds of inventories in a global distribution network, but the most common ones are:

- *Distribution centers* – Distribution centers (DC) are widely used in distribution systems and they have a dynamic purpose of centrally storing, mixing and moving products. In these goods are received in large volumes, stored briefly and then broken down into small individual orders required by the lower-tier general warehouses closer to the market. Sometimes DCs can also serve customers directly. In a global multi-echelon distribution system, it is common to have multiple DCs at different levels, which are conventionally referred as central, regional, national and local DCs depending on the location and role of the site relative to the network. (Arnold et al. 2011, pp. 296; Rushton et al. 2010, pp. 119)
- *General warehouses* – General warehouses are sites where goods are stored for longer periods and where the primary purpose is to have goods readily available to be able to fulfill customer orders. In a multi-echelon distribution system general warehouses respond directly to customer demand and they are the closest depots to the market. General warehouses get their products from DCs, but apart from this there is minimal handling, movement and relationship to transportation. (Arnold et al. 2011, pp. 296)
- *Cross-docks* – Cross-docks act as stockless intermediate points in the distribution network for the transfer of goods. Thus, they are simply meeting places for products to move from an inbound vehicle to an outbound vehicle. In the best-run cross-docking systems, all the required vehicles are arriving at approximately the same time so that products stay at the cross-dock for only a short period of time. This, though, requires a great amount of planning and coordination to succeed in the desired manner. (Watson et al. 2013, pp. 8-9)

Once the high-level inventory structure is derived, the final step is to decide how much inventory will be needed to fulfill customer demand. To be able to properly answer this, it is crucial to understand how inventories work in the ground level. When taking the inventory management point of view, an inventory on hand can be broken down into two main sections, as illustrated in Figure 6, both of which having its own specific function considering the entity.

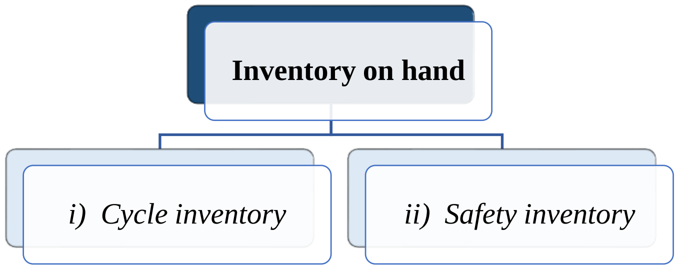



**Figure 6. Generic formation of inventories from an inventory management perspective**

These sections, their purposes and the related dimensioning bases are:

i. *Cycle inventory* – The cycle inventory, also referred as cycle stock (CS) is the average amount of inventory used to satisfy demand between the receipts of replenishments. The size of the cycle inventory is a result of the production, transportation and purchase of material in large lots, what companies tend to do to capture the economies of scale. With the increase in lot sizes, however, comes the increase in amount of inventory to be carried and hence inventory holding costs. Therefore, the trade-off companies face when deciding on the size of cycle inventory is the cost of holding larger lots of inventory (when the cycle inventory is high) versus the cost of ordering products frequently (when the cycle inventory is low). (Chopra & Meindl 2013, pp. 60)

ii. *Safety inventory* – The safety inventory, also referred as safety stock (SS) is the inventory to be held to counter uncertainty. If the world be perfectly predictable, only cycle inventories would be needed. Because demand is, though, uncertain and may exceed expectations, companies need to hold safety inventories to satisfy possible demand peeks. When determining the needed size of safety inventory, this turns to making a trade-off between the costs of losing sales due to not having enough inventory and the costs of having too much inventory. (Chopra & Meindl 2013, pp. 60)

As can be summarized, holding inventories impact directly on assets held, both availability and responsiveness provided, and costs incurred in the distribution network. Because of this supply chain practitioners completing network design studies should strive to find the right number, type and location of inventories that can provide the right level of responsiveness at the lowest possible cost and capital employed. (Chopra & Meindl 2013, pp. 59)

### 3.1.2 Transportation

The second building block of a global distribution network is transportation, which refers to the movement of products from one location to another as they make their way through the supply chain to customers. This is a significant supply chain driver because products are rarely produced and consumed in the same location. Transportation therefore has a major impact on both responsiveness and efficiency of distribution operations and is also an important cost element of the logistics costs incurring. (Chopra & Meindl 2013, pp. 409)

From the viewpoint of network design, companies' transportation systems consist roughly of facilities, routes and a collection of transportation modes, along which goods are being shipped. (Chopra & Meindl 2013, pp. 62) In a global context, products are moved ever-greater distances and that is why long-distance modes of transportation have become more and more important to the development of efficient logistics networks (Rushton et al. 2010, pp. 331). When considering intercontinental distribution, the viable transportation modes are *sea freight*, *air freight* and *express parcel*. All these modes rely on intermodality, mainly road transportation, for the initial and the final movement to its destination. Next, let us briefly discuss each of the transportation modes to be sure about their attributes and specific characteristics.

- *Sea freight* - In international trade, sea freight is the dominant mode for shipping all kinds of products and most companies tend to use it at some point of their supply chains. This is because of maritime offers by far the cheapest mode of transportation for large volumes and longer distances, but with the cost of speed and reliability. To meet the different transportation needs, there is a wide variety of vessels ranging from general cargo ships and bulk carriers to ferries and tankers. What is common to all these, is the strive to capture the economies of scale meaning that ships are built as big as possible. A significant trend in maritime in recent decades has also been the growth in the use of containers, which tend to increase the efficiency of water transportations by facilitating cargo shifting from a vehicle to another. The use of sea freight is clearly dependent on access to waterways and is limited to terminal-to-terminal routes needing expensive port facilities at both ends. In addition to ocean transportation, sea freight is also relative competitive in coastal shipping. (Chopra & Meindl 2013, pp. 414; Waters, D. 2009, pp. 414-415)

- *Air freight* – The low unit cost means that sea freight tends to be the standard mode of transportation for international trade, but sometimes it can be too slow. Then the only feasible alternative for longer distances is air freight, which offers a fast but rather expensive mode of transportation. Like maritime, air freight provides terminal-to-terminal shipping opportunity. Here though the need for high cost facilities and geography is not posing that much restriction. There are three main operative options for air transportation, which are charter service, scheduled cargo flights and scheduled passenger flights. In recent years major developments in the areas of additional cargo space, integrated unit loads, and improved handling systems have increased both the service capability and competitiveness of air freight. However, it is rare for the speed of delivery to be much more important than the costs and therefore air transportation remains limited to a small number of high-value, time-sensitive and lightweight items. (Chopra & Meindl 2013, pp. 412; Waters, D. 2009, pp. 416-417; Rushton et al. 2010, pp. 340)
- *Express parcel* – Express parcel operators, also referred as package carriers, are transportation companies such as DHL, UPS and FedEx, which carry small packages ranging from letters to shipments weighing about 70 kg worldwide. Package carriers use air, truck and rail in their transportation chains and they offer many service options ranging from overnight shipments to slower, postal like services, that give shippers control over the shipping time. However, in most cases the faster the service, the higher the corresponding price. In general, parcel services tend to be competitive in smaller shipment sizes but often cannot compete on the price with other transportation modes for larger or heavier shipments. The major advantage that they offer is, though, extremely reliable and rapid delivery. Thus, shippers tend to use express parcel for small and time-critical shipments. Package carriers also provide other value-added services such as package tracking and in some cases processing and assembling of products. (Chopra & Meindl 2013, pp. 412; Watson et al. 2013, pp. 105-106)

As a conclusion, the advantages and disadvantages of the underwent transportation modes is summarized in Table 2. These kinds of concise presentation of the major transportation characteristics tend to be unpredictably valuable when making network design decisions. The most appropriate mode for each situation depends on these features along with a wide variety of other factors such as the type of goods to be moved, product value densities, locations, distances and lead times. (Waters, D. 2009, pp. 409)

**Table 2. Collation of advantages and disadvantages of different transportation modes used in intercontinental distribution**

| | Advantages | Disadvantages |
|---|---|---|
| *Sea freight* | + Low unit cost<br>+ All types of cargo can be handled<br>+ Extremely good for heavy / large items and bulk commodities<br>+ High availability worldwide | – Long lead times<br>– Limited flexibility<br>– Poor reliability due to propensity to delays<br>– Cargo may be prone to damages due to extreme weather conditions<br>– Access to port facilities can limit feasible shipping points |
| *Air freight* | + Quick and reliable<br>+ Good for small-medium sized, lightweight and high-value shipments<br>+ Good for expediting situations | – High cost<br>– Moderate flexibility<br>– Location of airports can limit available shipping points<br>– Cannot be used for large, bulky or hazardous shipments |
| *Express parcel* | + Extremely fast and reliable<br>+ High customizability and flexibility<br>+ Competitive pricing for lightweight deliveries<br>+ Good for smaller shipment size<br>+ Good for time-critical / emergency situations | – Very expensive for heavier shipments<br>– Cannot be used for large, bulky or hazardous shipments |

Once the high-level transportation function along with the available modes has been covered, then the next critical aspect of the transportation building block from the network design point of view is transportation operations design. From this standpoint transportation operations can be broken down into two main types, which are *line-haul transportation* and *delivery transportation* as depicted in Figure 7. It is important to be aware of the major difference between these two, because they should be handled in a different way for both network design and operational purposes. (Rushton et al. 2010, pp. 438)

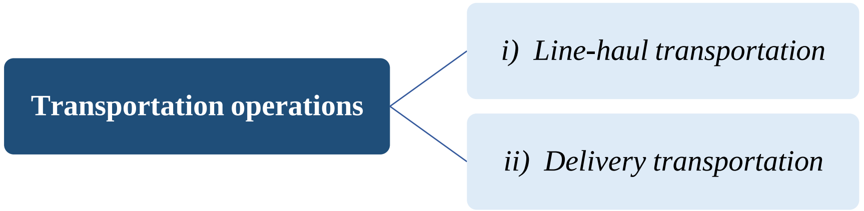



**Figure 7. Generic division of transportation operations from a transportation management perspective**

Next, let us briefly discuss these transportation types to be sure about their attributes and roles in terms of the bigger picture.

i. *Line-haul transportation* element or also referred as primary transportation is the movement of products in bulk to DCs from source or production points. These are usually done in as full loads as possible on large vehicles with the primary focus on moving products at minimum cost. This is because line-haul transportation is seldom regarded as an activity that adds value to business since there is no direct link to the final customer. (Rushton et al. 2010, pp. 438)

ii. *Delivery transportation* element or also referred as secondary transportation concerns delivering orders from DCs to the customers (either internal or external). Unlike the previous one, these involve direct contact with the customer and are thus often an important part of the customer service element in logistics. Because of this, costs are not the main operational criterion when deciding on delivery transportations (although they are important), but rather customer service related characteristics such as the speed, reliability and flexibility of the delivery. (Rushton et al. 2010, pp. 438-440)

As part of the transportation operations design, companies should also pay attention to the management side of it, which consist of tactical planning in the form of shipment routing as well as operational level management involving dispatching, monitoring and billing the shipments. What is interesting here from the viewpoint of network modeling is *dispatch planning in terms of consolidation* as well as *parallel multimodal use of transportation modes*. This is because these can further increase both the efficiency and effectiveness of the distribution network as described below. (Abele et al. 2008, pp. 295)

- Dispatch planning involves scheduling vehicles to transport all shipments within the time allotted at minimum costs. This is rather simple in the case of regular flows (= high volume density), where constant schedules can be used while in the same being able to capture the economies of scale in transportation. However, if deliveries are only needed sporadically (= low volume density), then vehicles have to be individually assigned to every small shipment. In this case it is advisable to strive to consolidate loads thus obtaining sufficient volumes to ensure cost-effective transportation. (Abele et al. 2008, pp. 288, 295)
- The parallel multimodal use of transportation modes involves using two or more different modes of transportation at the same time. Especially in intercontinental transportation the parallel utilization of air and sea freight can offer substantial saving potential while making distribution network both more efficient and more robust. This can also help meeting different delivery needs, thus making it possible to design a transportation network to address even the highest requirements of all the products. Parallel multimodality can easily be anchored as a feature of transportation management by for example proactively determining the share of air freight along with the specifications for which air freight will be used. The rest is then automatically allocated to and transported by sea freight. (Abele et al. 2008, pp. 288, 295-297)

As can be concluded, transportations play a critical role in a distribution network by defining how material flows within the network. The fundamental trade-off for transportation is done between the cost of transporting products and the speed with which these are transported. Using faster modes tends to increase responsiveness and transportation costs but decreases need to store and hence inventory holding costs. Therefore, from the viewpoint of network designing, transportation along with proper dispatch planning and use of different modes allow companies to adjust the location of their facilities and inventory levels to find the right balance between responsiveness and efficiency in the whole distribution network. (Chopra & Meindl 2013, pp. 62-63)

### 3.1.3 Third-party logistics (3PL) providers

The third and final building block of distribution networks is third-party logistics (3PL) providers, which refers to the use of an outside provider to perform company's logistics operations. Although outsourcing does not directly affect either network structures or modeling, it is an ever-prevalent trend especially in the context of global distribution. For instance, 3PLs are especially useful in emerging markets where suppliers need the capabilities of local warehousing but often do not have the volumes or resources to justify their own facility. Consequently, 3PLs have been brought up as a vital element of distribution networks in this study. (Arnold et al. 2011, pp. 287; Simchi-Levi et al. 2003, pp. 149)

As mentioned, 3PL refers to an outsourcing where a third-party service provider takes over all or part of the customer's logistics operations and materials management. Nowadays major part of companies either has or are taking this initiative to outsource logistics and thus these act as vital operators in supply chains. From the viewpoint of purchasers, 3PL providers are convenient, relatively inexpensive and extremely reliable. They come in all shapes and sizes and most of the providers can manage multiple stages and different operations of a supply chain. A typical service spectrum of a 3PL provider include the following:

- *Customs broking*
- *Export and import services*
- *Freights*
- *Delivery services*
- *Warehouse operations*
- *Packaging*
- *Local sourcing / purchasing*
- *International trade management*
- *Global transportation optimization*
- *Supply chain planning*

(Monczka et al. 2008, pp. 565; Simchi-Levi et al. 2003, pp. 149)

Modern 3PL arrangements involve long-term commitment and often various functions or even process management. 3PL relationships are thus typically more complex ones than traditional logistics outsourcing, "*they tend to be more like strategic alliances*". (Simchi-Levi et al. 2003, pp. 149) This is why companies should pay notable attention to the selection of the 3PL provider as well as to the implementation process of logistics cooperation. The key here is to find an adequate partner that shares the same intentions with shared risks and rewards, and can meet the company's logistical requirements and specific performance measures. Both parties should also be committed to devoting the time and effort needed to make the relationship successful and mutually beneficial. (Simchi-Levi et al. 2003, pp. 152-153)

In general, most of the generic advantages and disadvantages of strategic alliances apply also to 3PL relationships. Based on the findings of Simchi-Levi et al. (2003, pp. 150-151) and Monczka et al. (2008, pp. 567) these are concluded in the following Table 3.

**Table 3. Summarization of the advantages and disadvantages of 3PL strategic alliances**

| Advantages | Disadvantages |
|---|---|
| + Enables concentration on core business activities<br>+ Provides convenience and operational flexibility<br>+ Releases capital to be committed as well as running costs<br>+ Provides the economies of scale and scope<br>+ Improves overall service performance<br>+ Offers readily accessible visibility to logistics via linked tracking and information systems<br>+ Enables agile reacting to the problems of scale where either the number of customers or the volumes alter | – Renounces control over operations, ownership and expertise<br>– Increases dependency on other parties<br>– Exposes to a possible loss of integration between sales and supply<br>– Induces a changeover in costs and operational problems<br>– Sacrifices the key logistics service differentiation possibility |

As can be seen, it is possible to obtain a significant operative advantage from cooperative 3PL relations. However, there are also some risks and disadvantages involved that companies need to heed and try to manage in the best possible way, in order the alliance to be thriving.

When it comes to distribution network designing, outsourcing and the use of third-party service providers appear here mainly through costs, which tend to be by nature purely variable instead of fixed (as in self-acting implementation). For instance, when companies use 3PLs to transport shipments, they pay the commercial freight rate, which is often quoted per kg per line (Waters, D. 2009, pp. 409). Similarly, in warehousing the 3PL operator charges the company per unit stored or handled and thus there will be only a simple variable cost to include in calculations. (Watson et al. 2013, pp. 131)

## 3.2 Strategic trade-offs and structural archetypes of a distribution network

As mentioned earlier, to thrive in the market and to capture competitive advantage, companies need to achieve the so-called strategic fit between competitive and supply chain strategy, which in other words refers to the consistency between customer priorities that the competitive strategy hopes to satisfy and supply chain capabilities that the supply chain strategy aims to build. This involves developing a supply chain strategy that is aligned with both the competitive strategy and related objectives. In brief, this supply chain strategy specifies the broad structure of the supply chain including decisions like what is the specific role of each function, how these should be operated as well as what is the right way to manage and coordinate material and information flows within the chain. (Chopra & Meindl 2013, pp. 32-33)

One of the most fundamental decisions of supply chain strategies is regarding the network design and the choice of distribution channels to be used. Due to the interdependent nature of logistics, this inevitably involves making choices between different aspects and issues of distribution. The most critical trade-offs that managers end up deliberating when making network related decisions are:

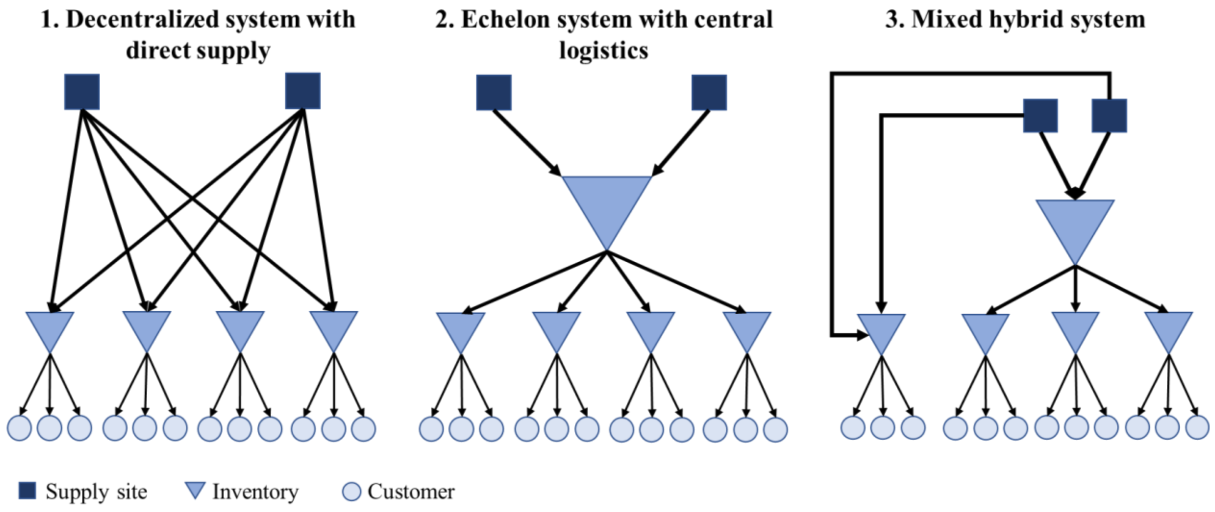
*"The strategic trade-off between customer responsiveness and total logistics costs"*

*"The constructional trade-off between inventory and transportation costs"*

*With the customer responsiveness and total logistics cost trade-off*, the main concern is the strategic choice between responsiveness and efficiency provided by logistics. In general responsiveness is defined as the ability to meet customers' demand quickly, preferably straight from the facing stock. Therefore, customer service is highly dependent on logistics operations, and reducing total logistics costs typically come at the expense of customer service. For example, if an inventory is stored in a centralized warehouse and/or deliveries are accumulated from a longer period of time and shipped out as a bunch, a company may be able to save in total logistics costs. This weaker responsiveness may though cause the loss of revenue due to customer dissatisfaction. Given this trade-off, the key strategic choice thus seems to wrap around the level of customer service the company seeks to provide. (Chopra & Meindl 2013, pp. 430-431; Simchi-Levi et al. 2004, pp. 38-39)

*With the inventory and transportation cost trade-off*, the main concerns are the level of inventory aggregation in the network and the transportation modal choice. Here the level of inventory aggregation will on a large scale dictate the number of stockholding points and how much inventory is stored in the network along with the related costs. To balance this, the choice about transportation modes is to be decided, which comparably determine the lead times, the minimum shipment quantities and above all the costs of transportation. For instance, when using a centralized network structure with aggregated inventories, both facility and warehousing costs can be reduced but with the cost of faster and more expensive transportation modes. However, when leaning on decentralized network structure with local inventories, slower and more economical transportation modes can be used, but with the cost of higher facility and warehousing costs. (Chopra & Meindl 2013, pp. 424-430)

As can be noticed, there are various construction alternatives that can be used within a distribution network. All these, though, intertwine to the fundamental questions of what type of warehouse structure should be generated and whether the products should be shipped directly to the markets or should waypoints be used. (Friedli et al. 2014, pp. 56-57; Rushton et al. 2010, pp. 50) Based on this and the critical trade-offs introduced above, a generic set of global distribution network archetypes can be derived. These are delineated in Figure 8 below.




(adapted from Friedli et al. 2014, pp. 57; Rushton et al. 2010, pp. 178-179)

**Figure 8. Structural archetypes of a global distribution network**

The three main layouts are:

1. *Decentralized system with direct supply* – Decentralized systems consist of a set of local sites, which are supplied directly from centralized supply sites. In the system each of the local site is serving a specific market region, but there can also be direct shipments from the supply sites (for example in case of an emergency). Therefore, there tend to be two types of direct supplies – the supply of full replenishment loads and the supply of smaller parcels. The major advantages of this structural alternative are the elimination of intermediate inventories and the simplicity of operation and coordination. However, significant stockholding is needed at the local sites due to large lot sizes needed to make long-distance replenishments cost-effective. (Friedli et al. 2014, pp. 57; Chopra & Meindl, 2013, pp. 442; Rushton et al. 2010, pp. 179)
2. *Echelon system with central logistics* – Echelon systems conversely compose of multiple stockholding points at several stages and thus involve the flow of products through a series of locations from the point of supply to the final destination. There are usually various levels and links within these systems, but the most basic structure involves supply sites, a central stockholding point and a set of local sites close to the markets. Here the supply sites supply the central warehouse or a dedicated consolidation center, which then further supplies the local sites according to need. The main advantages of this structural alternative are the lower overall transportation costs along with increased responsiveness. However, inventory and system and administration costs tend to increase in this due to the additional stockholding. (Friedli et al. 2014, pp. 57; Chopra & Meindl, 2013, pp. 442; Rushton et al. 2010, pp. 179)
3. *Mixed hybrid system* – Mixed hybrid systems are a compound of the previous ones that combine the elements of both direct and echelon systems in a tailored manner to improve the responsiveness of the network and reduce costs. In the example, the structure consists of the main multi-echelon distribution channel that leans on central logistics, but alongside this there is also a direct supply channel that serves a specific market region, for which high-level inventory aggregation is not reasonable due to demand characteristics of the products being supplied. The major advantage of this structural alternative is that the network can best match the various needs of individual products and markets. However, managing and coordinating this type of network can be complex, because various procedures need to be used in daily operation. (Chopra & Meindl, 2013, pp. 442; Rushton et al. 2010, pp. 179)

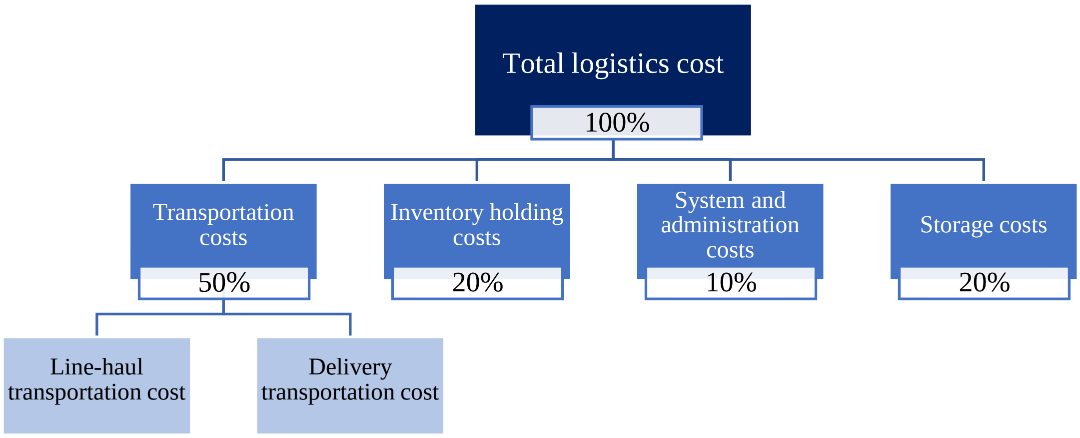
As can be seen, the network and channel structures can differ notably from alternative to another. An individual company renewing its distribution operations and network construction therefore have to undergo a number of different options and strive to find a suitable network design alternative to fulfill its distribution needs. Usually, though, the “one-size-fits-all” approach is not that appropriate in most instances and hence companies need to further devise their networks in order to be able to serve many customer segments with a wide variety of products across multiple tailored channels. (Chopra & Meindl, 2013, pp. 42)

When internally tailoring the archetypes, the key issue is to design a network that is able to be responsive to some products and efficient for others. This usually involves sharing the rootstock of the network with all products while having separate procedures for the special cases. For instance, bulk products needing high responsiveness may be stored at local sites close to the customers, whereas specialties are held at a centralized stockholding point to cut costs. In other cases, all products may be stored in the same central warehouse, but goods requiring a higher level of responsiveness may be shipped using fast transportation modes like parcel while others are sent by slower and more cost-effective means such as maritime. By this way appropriately tailoring its network, a firm can achieve the demanded varying level of response at a low overall cost. (Chopra & Meindl, 2013, pp. 42-43) In order to success in this, companies should though be aware of factors driving the network planning and how to uncover a suitable distribution chain for each case. These issues will be explored in more detail in the following sections.

## 3.3 Costs and cost structure of a distribution network

To plan a cost-effective distribution network solution, it is necessary to be aware of the individual logistics cost elements of distribution, how these will interact as the network alternates (different number, size, type and location of depots) as well as how the total logistics cost builds up and what this will be in different scenarios. Without this information it is impossible to measure the efficiency of the current network or gain the necessary insight into the distribution operations to allow for successful logistics planning and management. (Rushton et al. 2010, pp. 120)

According to Rushton et al. (2010, pp. 120-125) the typical logistics cost elements of a distribution network are *transportation costs*, *inventory holding costs*, *system and administration costs* and *storage costs*. These along with their shares form the generic cost structure of a distribution network as shown in Figure 9. Inevitably, the cost element shares will vary from one company to another, but here a typical situation in global scene is delineated.




(Rushton et al. 2010, pp. 10, 120-125)

**Figure 9. Delineation of distribution networks' cost structure and typical cost element shares in global scene**

Based on their characteristics, the costs are categorized for modeling purposes either as *variable* (costs that are dependent on the number of units that pass through a facility) and *fixed* (costs that are a one-time charge independent of the volume). In network design context, this allotment is, though, often a somewhat trivial and there is no correct answer what cost is "variable" and what is "fixed" due to various reasons (for example increasing use of 3PL services in global supply chains). Therefore, the key is to understand how these costs work and affect the whole to determine how to use them in one's network design study. (Watson et al. 2013, pp. 127-128) Next, each cost element, their related characteristics and how these eventually form the total logistics cost in a distribution network will be discussed more closely.

The first and often the most critical cost element in distribution is *transportation costs*, which consist of two components that are the *line-haul transportation cost* and the *delivery transportation cost.* As was previously stated, the line-haul transporting refers to shipping products in bulk to DCs from the point of source or production, while the delivery transporting concerns delivering orders from DCs to local sites or directly to customers. Transportation costs are essentially dependent on the distance that is to be travelled and the number of different lines within the system. Due to this line-haul costs tend to increase (because the greater the number of lines the shipping volume is distributed) whereas delivery costs usually reduce (because the less the stem of distance) the greater the number of depots. Because the delivery cost component mainly dominates the cost entity, the overall effect of combining these two components is that total transportation costs will reduce, the greater the number of depots in the network. (Rushton et al. 2010, pp. 121-122)

Another important cost element considering distribution networks is the *cost of holding inventories*. This includes expenses incurred because of the volume of inventory is carried, and divides into three main components which are:

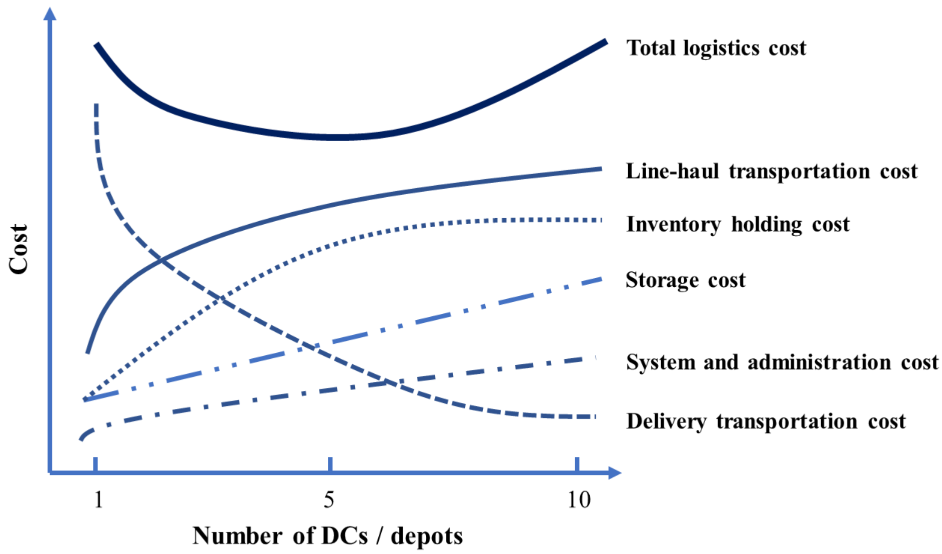
- *Capital cost* – the financing charge of money invested in the stock. To reflect this, companies usually apply their prevalent cost of capital or an opportunity cost of tying up capital that might otherwise be producing a return if invested elsewhere.
- *Storage cost* – the cost of space, equipment and workforce needed to store and handle goods in the inventory.
- *Risk cost* – the cost of risks involved in carrying an inventory, which may occur through damage, pilferage, stock obsolescence or possible deterioration of stocked items among other things.

As can be supposed, the costs of holding inventories increase as physical inventory increases. Due to this, networks' inventory holding costs increase the greater the number of depots. Inventory holding costs are usually defined as a percentage of the monetary value of inventory per unit of time (principally year) and they vary heavily depending on the company and industry in question. Usually, the percentage is, though, around 20%-40% of the monetary value of inventory. (Arnold et al. 2011, pp. 201-202; Rushton et al. 2010, pp. 123-124)

The third cost element to be considered in distribution networks is *system and administration costs* or briefer *system costs*. These costs represent a variety of information, communication and management requirements ranging from order processing and invoicing to producing load assembly lists. The processes may still be manually operated but are more likely to be automatized using technology (at least in some degree). The system costs like all the previous ones tend to increase the greater the number of depots. (Rushton et al. 2010, pp. 124)

The final cost element in the listing is *storage costs*, which include all the depot related fixed costs. Here the major breakdown goes between building, building service, labor, equipment and management costs. Storage costs vary based on different business-related factors such as industry, regional location, product type, annual volume throughput and building characteristics. With respect to other parts of the distribution system, the storage costs are mainly dependent on the size and the number of depots within the distribution network. The effect of size can be illustrated by the economies of scale experienced with larger depots and the effect of repetition by the increased cost burden as the number of depots in a distribution network increases. (Rushton et al. 2010, pp. 120-121)

When it comes to the total logistics cost of the distribution network, the functional cost elements described above can be built together to get the overall cost incurring. This so-called total cost approach along with the high-level impacts of a different number of depots on distribution costs is illustrated in Figure 10 below. Considering distribution network designing, the overall cost effects of using a different number of depots can be demonstrated by a such graph. Here the top line shows the total logistics cost, which is obtained by adding up the individual cost curves of the functional cost elements.

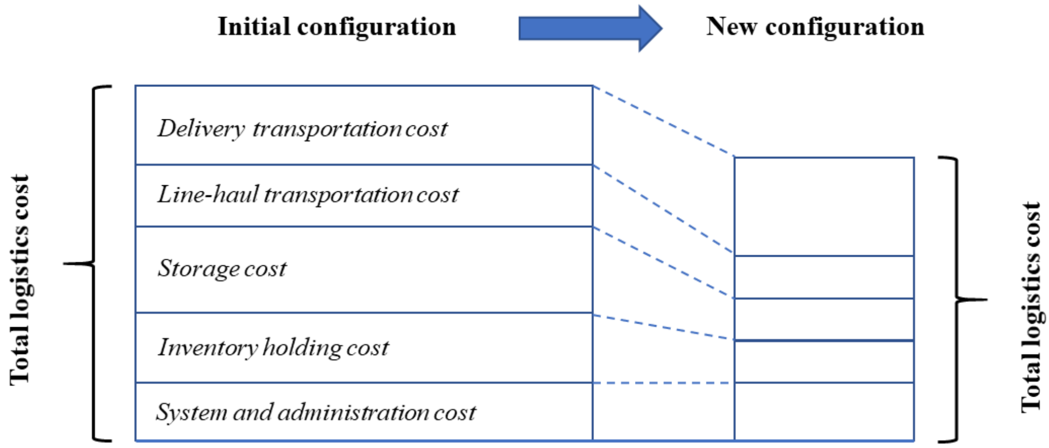



(adapted from Rushton et al. 2010, pp. 125)

**Figure 10. Relationship between total and functional logistics costs as the number of depots change in a distribution network**

In the example presented in this figure, it can be seen from the graphs that the least expensive option measured by total logistics costs occurs around 5-to-6 depots. In practice, however, these results will depend on numerous factors such as industry, product type, business requirements, the required service level and the geographic distribution of demand among other things. Hence, the process of network planning is not just a question of costs, but other issues have to be taken into account as well. (Rushton et al. 2010, pp. 125-126)

An essential feature of this total cost approach in terms of network design and operations planning is also the concept of *trade-off analysis* delineated in Figure 11 below, which can be used to collate cost structures and underlying changes in the major cost elements between alternative network configurations. In the figure, the outcomes of a fictional network rationalization project are delineated where a reduction in number of depots has yield to significant declination in overall logistics costs. As can be seen from the trade-off analysis although there is quite some increase in delivery transportation costs, savings in other cost elements have produced overall cost benefits. (Rushton et al. 2010, pp. 126)




(Rushton et al. 2010, pp. 126)

**Figure 11. Trade-off analysis delineating changes in total logistics costs and related cost structure as the network configuration is altered**

As can be concluded, the number of facilities along with their sizes and locations tend to be a crucial factor in the success of a distribution network. In fact, some experts suggest that 80% of the costs of the supply chain are locked in with the network design when determining the locations of these facilities and optimal flows of material between them. The most successful companies recognize this and place significant emphasis on the process of strategic network design and analysis, which is covered in more detail in the following chapters. (Watson et al. 2013, pp. 1)

## 3.4 Factors influencing distribution network structures

As has previously been emphasized, a distribution system is an interrelated entity where many things dynamically affect each other. Regarding to this, various factors have been described within the literature as significant when designing a distribution network to be used in this system. Lovell et al. (2005, pp. 143) have successfully composed these and grouped them as *product*, *market, sourcing* and *operational environment* specific factors. With additions drawn from the findings of Chopra & Meindl, Christopher, Jonsson, Rushton et al. and Simchi-Levi et al. the most relevant factors influencing distribution network decisions are listed in Table 4 below.

**Table 4. Factors influencing distribution network decisions**

| Group | Influential factor |
|---|---|
| *Product characteristics* | • Physical size and weight<br>• Product value<br>• Product's risk characteristics |
| *Market factors* | • Customer service needs<br>• Demand<br>○ Level (throughput)<br>○ Variability (predictability)<br>• Demand location and regional dispersion |
| *Source factors* | • Source of origin<br>○ Number of suppliers<br>○ Focused production<br>• Supply lead times<br>• Supply flexibility |
| *Operational environment factors* | • Political stability<br>• Legislation and government regulation<br>• Existing logistics infrastructure and transportation mode availability<br>• Trade incentives-barriers / taxes / customs duties / exchange rates |

Next each group and the associated factors are briefly discussed with the intention to elucidate why and in which way these are likely to affect the network design.

### 3.4.1 Product characteristics

One of the most influencing and hence important factors to consider when preparing network design studies are the products to be distributed. These have multiple characteristics that tend to have an instant impact on the operation and development of a distribution network. The impacts are visible both in the structure and the costs of the network. (Rushton et al. 2010, pp. 90) The list of influential product characteristics could continue endlessly, but from a viewpoint of network design the most important factors are:

- *Physical size and weight* – Products' volume and weight characteristics, often referred as the volume-to-weight ratio, tend to have a significant influence on logistics costs and are thus commonly associated in product segmentation and supply chain selection. Generally, both the transportation and warehousing cost are usually greater for high volume-to-weight than low volume-to-weight products. This is because high-volume products use up a lot of space and are therefore less efficient for distribution. Another reason is that logistics service providers tend to build their rate cards in the way that they prefer high-weight shipments over high-volume shipments. As for network design, these aspects should be taken into account in both transportation and inventory planning to be able to conduct the distribution operations cost-effectively, was the products in question then whatever like. (Rushton et al. 2010, pp. 90)
- *Product value* – Product value usually also has a major impact on network design. Once again, it is useful to assess the value effect in terms of weight in the form of a value-to-weight ratio or product value density (PVD). Generally spoken, products with a low value-to-weight ratio incur relatively higher transportation but lower inventory holding costs compared with high value-to-weight products. This is because high-value products are more likely to be able to absorb the associated transportation costs, but conversely these tie up more capital in the stock. When it comes to network design, high value-to-weight products are preferred to be stored in a centralized manner and delivered directly in order to avoid substantial stockholding and hence growing warehousing costs. On the contrary, the opposite goes to low value-to-weight products. The end decision is, though, affected by various other factors as well. (Rushton et al. 2010, pp. 91; Lovell et al. 2005, pp. 144)

- *Product's risk characteristics* – Some products to be handled may have characteristics that present some degree of risk associated with their distribution (ranging from fragility and perishability to extreme value or even hazard). The need to mitigate and manage these risks means that special procedures and designs must be used in both transportation and warehousing. As with any form of specialization, there will, though, be costs incurred, that should be addressed when making network design decisions. (Rushton et al. 2010, pp. 92) Examples of these risks and the needed specializations include the following:
  - <u>Products with short shelf life</u> like certain chemicals or lubrications should be stored in moderate quantities with continuous and fast replenishments in place in order to avoid spoilage. (Lovell et al 2005, pp. 144)
  - <u>Fragile products</u> like microchips tend to need special packaging to mitigate shocks caused by both transportation and handling. Often these kinds of products are, though, shipped via air freight or parcel, which are not that prone to damages. (Rushton et al. 2010, pp. 92)
  - <u>Hazardous products</u> like batteries might need special labeling and packaging along with the use of limited unit load sizes. Sometimes these must even be isolated from other cargo, but the requirements differ from situation to another. (Rushton et al. 2010, pp. 92)

### 3.4.2 Market factors

Another significant group affecting network design decisions is market specific factors, which in general consist of elements that are upwelling from the market and clientele. Once again, these tend to have a direct impact on distribution system and its operations and are visible both in the costs and in the structure of the network. Afresh, from a wide spectrum of different elements, the most significant factors from the viewpoint of network design are:

- *Customer service needs* – As has been stated, distribution is all about bringing products available to customers, and so customers and their service needs should be one of the first factors to be considered when designing distribution networks. From the logistics point of view, customer service includes all activities related to the flow of materials which create value for customers. When it comes to distribution, often components related to fulfilling the order-to-delivery process are the most vital. Thus, the service components that should be taken into account in network design are:

i. Product availability – indicates the extent to which stock items are readily available in stock when they are needed
ii. Delivery time – refers to the time that elapses from the receipt of a customer order to the fulfillment of the delivery
iii. Delivery precision – indicates the degree to which deliveries take place at the times agreed with the customers
iv. Delivery reliability – refers to the quality of delivery in terms of right products being delivered in the right quantity
v. Delivery flexibility – indicates the ability to adapt to and comply with changes in customer requirements in agreed and ongoing orders

In practice, different customers tend to appreciate different aspects of service and therefore it is important to be aware of the customers' service preferences and how they might affect the distribution system. For example, companies that target customers who require high responsiveness with great availability and short delivery times need a multi-echelon distribution network with local sites close to markets. However, when there are customers who can tolerate longer lead times the case is usually opposite, and hence more straightforward structural alternatives can be considered. (Jonsson 2008, pp. 84-85; Chopra & Meindl 2013, pp. 81-82)

- *Demand level* – Demand level or throughput typically also has an important effect on the design of the physical network. Here, this tends to influence areas such as site locations, warehouse sizes and modes of transportation. Typically, as the volumes increase a more decentralized distribution structure with a higher number of stockholding points closer to customers along with the use of slower transportation modes can be justified as the economies of scale are getting more achievable. However, these decisions are again dependent on other influential factors such the products characteristics and the customer service requirements mentioned earlier. (Lovell at al. 2005, pp. 145, 151)
- *Demand variability* – Like throughput, demand variability also has a significant influence on distribution network design. This is because demand variability or from a logistics planning viewpoint its predictability greatly affects stockholding and the size of the inventory. Generally, as demand variability increases its predictability decreases, and to be able to effectively respond to demand in any situation greater safety stocks are needed. The

effects of demand variability could be reduced by centralizing inventories and aggregating demand across locations, as it becomes more likely that high demand from one customer will be offset by low demand from another. Therefore, if the market to be served is affected by high demand variability a more centralized distribution system with central logistics is recommended. This is, though, greatly affected by the industry characteristics, customer service requirements as well as the size and spread of the market. Demand variability is often measured in the form of a standard deviation to average demand ratio also known as the coefficient of variation (CV). (Simchi-Levi et al. 2003, pp. 64-66)

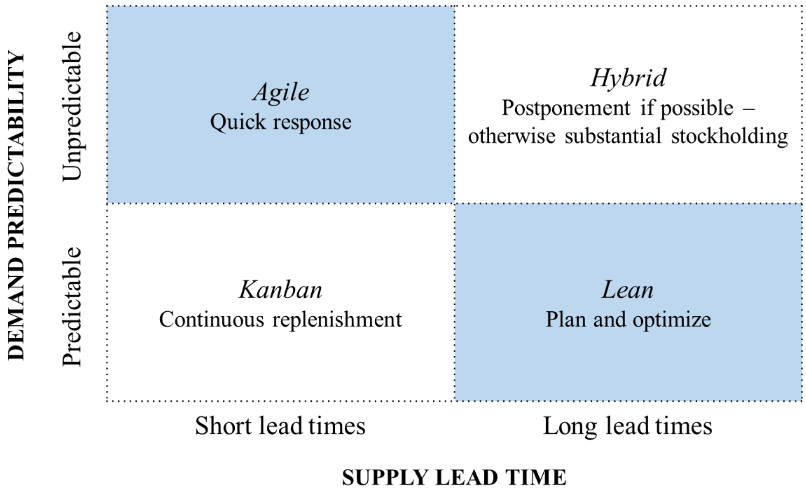
- *Demand location and regional dispersion* – The size, the spread and the density of the market to be served has likewise impact on the network structure. Often if a market is very large and spreads widely from a geographic viewpoint, then it is common to use echelon systems. Here there are multiple stockholding points at different levels, which is supported by central logistics along with a number of different movements for the products as they make their way from the source of origin to end customers. Comparably, when a market has only a handful of customers in a limited geographical area, then more straightforward systems with direct supplying should be used. Similarly, if there is substantial regional dispersion in demand volumes in the service area, this also advocates more direct means to design distribution network and meet demand. However, this is greatly dependent on the aforesaid size and spread of the distribution area. (de Leeuw et al. 1999, pp. 110; Rushton et al. 2011, pp. 56)

### 3.4.3 Source factors

Source factors consist of both production and purchasing characteristics, which in distribution context are often outside the sphere of influence and thus taken as given. Therefore, these usually act as constraints to network design by limiting the alternatives and guiding the decision in a certain direction. Whether internal (production) or external (purchasing) sourcing, the most influencing factors from a network design viewpoint are basically the same. These are:

- *Source of origin* – Restrictions on the source of origin (stemming either from a limited number of suppliers or focused production) usually mean that distribution chains are forced to start at certain geographic points. This correspondingly impacts on distances to be covered in distribution, the number of transportation lines as well as lead times while also restricting the playing field. However, if the case is opposite and one can freely choose where to source and supply, then there is much more room for modeling and network optimization.

- *Supply lead times* – An important factor on the supply-side is likewise the length of supply lead time, which covers the time frame from placing an order to physically receiving the products. In logistics planning this is usually coupled with demand predictability, because these two tend to dictate what kind of strategic initiatives could be considered in each case to be able to effectively respond to demand. Based on the findings of Christopher (2011, pp. 101) four generic supply chain strategies can be derived from the combinations of these two characteristics. The strategies are depicted in a matrix form in the following Figure 12.




(adapted from Christopher 2011, pp. 101)

**Figure 12. Portrayal of generic supply chain strategies in terms of supply lead times and demand predictability**

As can be seen, under this segmentation "reactive" supply chain initiatives should be applied when there are short lead times. In those cases where demand is predictable, a Kanban type of solution with continuous replenishments is recommendable. Consequently, where demand gets more unpredictable an agile quick response type of strategy supported with a flexible supply chain and low inventories tend to be the most suitable alternative to meet the rapidly changing needs of the market. Conversely, when supply lead times are longer more "proactive" procedures should be harnessed for use. Where demand is predictable, it is advised to try to plan and optimize supply chain operations in a Lean manner to be able to respond to the demand in the most effective yet operatively efficient manner. Usually, this requires accurate demand forecasts and good knowledge of the future. However, when demand gets more unpredictable then this Lean type of responding becomes problematic and other approaches need to be explored. In this case, the priority should be in seeking ways to reduce lead times, because the variability of demand is almost certainly outside the company's control. This should likewise be reinforced with postponement, or if this is not possible (often the case) then with substantial stockholding to be able to meet the varying demand. (Christopher 2011, pp. 101-102; Rushton et al. 2011, pp. 113)

- *Supply flexibility* – Supply flexibility along with lead times and stockholding tends to dictate the company's ability to adapt to and comply with changes in customer requirements. Here the flexibility part usually includes things like lot sizes, supply frequency and product ranges which the distributor may want to influence to be able to meet the demand in an effective manner. (Jonsson 2008, pp. 84, 89; Simchi-Levi et al. 2004, pp. 4-5)

### 3.4.4 Operational environment factors

The operational environment with its different aspects is obviously an important thing when designing distribution networks. In general, the operational environment is influenced by issues such as:

- *Political factors:* political stability
- *Legal factors:* legislation, government regulation
- *Infrastructure factors:* existing logistics infrastructure, availability of transportation modes
- *Macroeconomic factors:* trade incentives-barriers, taxes, customs duties, exchange rates

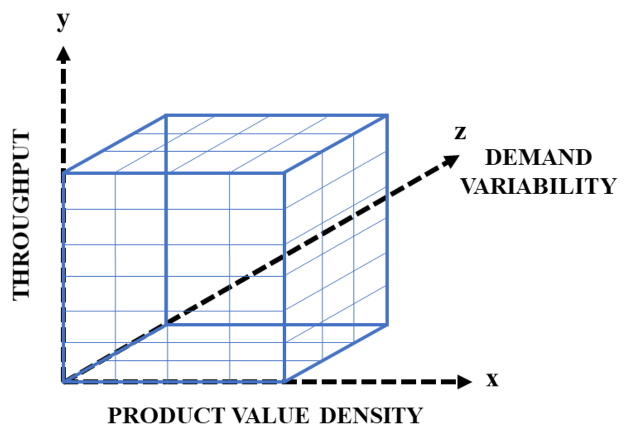
From the viewpoint of network design these again, though, act as constraints to a company planning its logistics and tend to guide the solution to one direction or another. For instance, Switzerland allows cross-country freight movements only by rail, which therefore dictates the modal choice and, in some extent, also the network structure that can be used in distribution. Another example is the formation of the European Union, through which all trade barriers along with additional taxes and customs duties across the continent have fallen as the European countries united as an economic and monetary union. This has consequently spurred both the integration and centralization of distribution networks and logistics operations in companies operating Europe-wide. (Lovell et al. 2005, pp. 145-146; Chopra & Meindl 2013, pp. 121-126)

## 3.5 A framework for supply chain segmentation and network design

Supply chains, in particularly in the context of global distribution, have to serve a wide range of products and different customers. Due to this diversity an "one-size-fits-all" approach to logistics is not appropriate in most instances. Thus, some form of supply chain segmentation and situation-specific design is needed in order to satisfy the various needs of the market. (Lovell et al. 2005, pp. 142; Rushton et al. 2010, pp. 110)

From the factors influencing the network design along with the common supply chain trade-offs and major cost elements of logistics, it can be seen that there is this a somewhat tight set of drivers "running the show", which are: *demand volume (throughput), demand variability (predictability), product value* and *product size and weight*. By applying the knowledge of product characteristics, these four can be further compressed to three by wrapping up product value with product size and weight to form the product value density (PVD). So, these three are now the key drivers for supply chain segmentation and design. (Lovell et al. 2005, pp. 149)

Based on the previous research reasserted with their own findings, Lovell et al. (2005, pp. 149-153) have been able to produce a generic framework for supply chain segmentation and design by combining these three drivers along with their characteristics to a three-dimensional diagram shown in Figure 13. In the framework the selection of the most appropriate supply chain designs is considered in terms of the drivers' impact on two of the most important network decisions: *the level of centralization needed within the network* and *the transportation modal choice*.




(Lovell et al. 2005, pp. 150)

**Figure 13. A framework for supply chain segmentation and design**

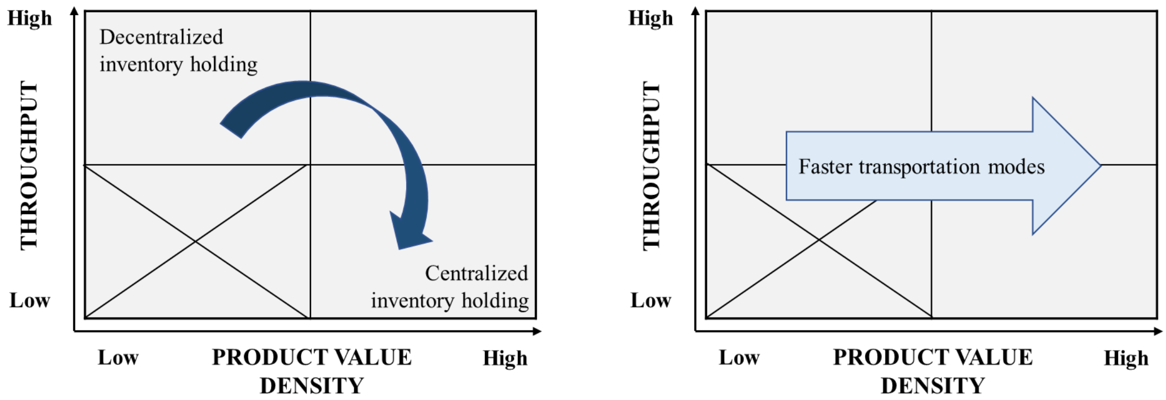
In order to make it easier to interpret the framework, the diagram can be divided and reviewed through two-dimensional slices of the three-dimensional space, which are:

1. *Product value density (PVD) – Throughput* (x-y)
2. *Demand variability – Throughput* (z-y)
3. *Product value density (PVD) – Demand variability* (x-z)

Next these will be covered in the listed sequence by paying attention to the drivers and how they impact on network design. (Lovell et al. 2005, pp. 150)

### 3.5.1 Impacts of PVD and throughput on supply chain design

The 1st slice (x-y dimension) of the framework constructs of product value density (PVD) and throughput, and in Figure 14 is outlined the impacts of these on the design alternatives of a supply chain and yet broader on network design.




(Lovell et al. 2005, pp. 152)

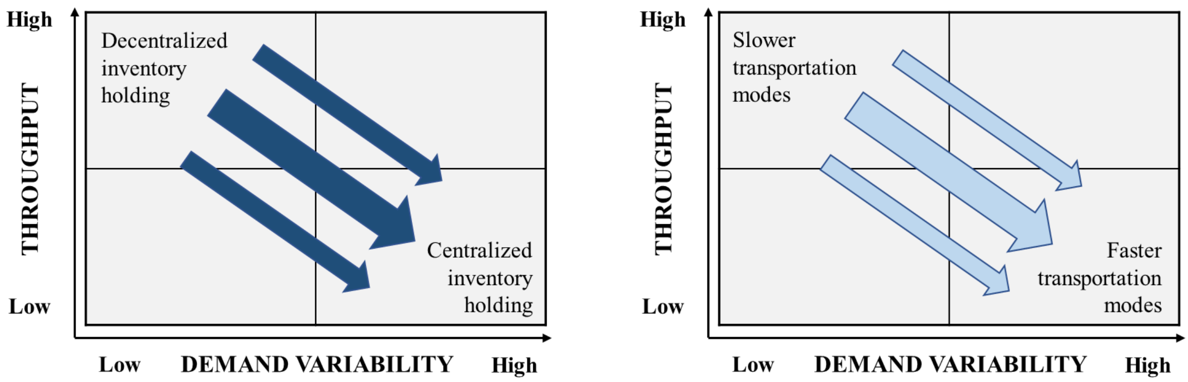
**Figure 14. Impacts of PVD and throughput on level of centralization and transportation options in supply chain design**

As can be seen from the diagrams, high product value density accompanied with low throughput tend to lead to a close-knit network design with centralized inventory holding, because as product values increase the capital tied up in warehouses and so inventory holding costs also increase and this advocates design alternatives that minimize stockholding. In conjunction, this also drives the decision for faster transportation modes because as stockholding centralizes distances tend to increase, and to offset the undesired increase of lead times (and the resulting need for additional replenishment stocking in possible decoupling points) as well as preserve effectiveness, speedier transportations are needed. This is also due to the fact, that it is more cost-effective to transport high-value products via fast modes because they tend to tie up so much funds in transit. (Lovell et al. 2005, pp. 152; Rushton et al. 2010, pp. 341)

Conversely, as throughput volumes increase and product value densities decrease this provides opportunities to move to a more widespread and decentralized network with a higher number of stockholding points close to the customers, as the economies of scale and scope are getting more achievable. Likewise, as inventories and material flows within the network increase it is more justified to use slower and more economical transportation modes. In the framework, the zone where both product values and their throughputs are low is crossed out because products that fall into this segment are not that prolific. Therefore, the decision of offering such products should be highly impugned. (Lovell et al. 2005, pp. 152-153)

### 3.5.2 Impacts of demand variability and throughput on supply chain design

The 2nd slice (z-y dimension) of the framework consists of demand variability and throughput, and in Figure 15 is illustrated the impacts of these on the design alternatives of a supply chain and yet broader on network design.




(Lovell et al. 2005, pp. 150-151)

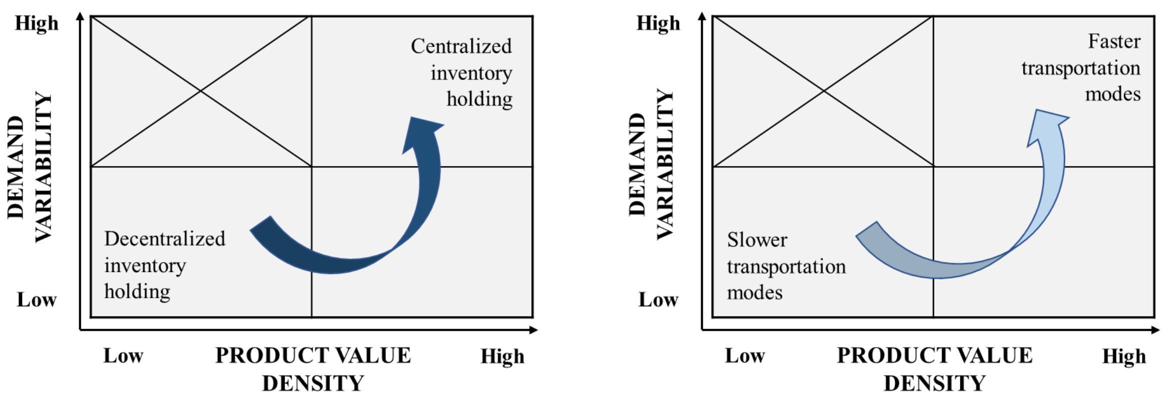
**Figure 15. Impacts of throughput and demand variability on level of centralization and transportation options in supply chain design**

As demand variability increases (predictability decreases) the need for safety storages and hence overall stockholding in a network increases in order to be able to effectively respond to demand in any situation. As can be seen from the diagrams, this tends to be offset by condensing the network and centralizing stockholding, as the pooling of stocks can substantially lower the need for storage and so yields to lower holding costs. However, as was previously discussed the centralization strategy that is encouraged here, increases transportation distances within the network, which in turn should be offset by preferring faster modes of transportation. (Lovell et al. 2005, pp. 150-151)

Whereas, as demand variability decreases (predictability increases) and throughput levels increase, often by the same token, a more decentralized network alternative with stockholding points close to markets can be applied as the augmenting economies of scale and scope justifies this more disperse design. Likewise, as was previously stated, when inventory structure becomes more widespread and this way more responsive to customer demand, slower transportation options can be considered. (Lovell et al. 2005, pp. 151)

### 3.5.3 Impacts of PVD and demand variability on supply chain design

The 3rd and final slice (x-z dimension) of the framework consists of product value density (PVD) and demand variability, and in Figure 16 is demonstrated the impacts of these on the design alternatives of a supply chain and yet broader on network design.




(Lovell et al. 2005, pp. 151-152)

**Figure 16. Impacts of PVD and demand variability on level of centralization and transportation options in supply chain design**

As can be seen from the diagrams, both product value density and demand variability seem to have the same kinds of impacts on network design alternatives. As they increase, both drivers tend to encourage more condensed network structure with centralized stockholding and the use of fast transportation modes. However, as the effect of the drivers decrease a more widespread network structure with decentralized stockholding and slower transportations can be considered in order to achieve both effectiveness and cost-efficiency in the network. In the framework, the zone where product value density is low and demand variability is high is crossed out because the decision of offering such products that fall into this segment should be questioned in terms of efficient and effective supply chain management. (Lovell et al. 2005, pp. 151)

So, both of these drivers lead to the same courses as they differ, but this is, though, due to different reasons as have already been discussed in previous sections. As a recap, as product values increase the capital committed to warehouses and so the inventory holding costs also tend to increase and this drives the need to minimize stockholding, which can be achieved through network centralization. Analogously, as demand variability increases (predictability decreases) the need for safety storages compulsively increase, and to offset this, the pooling of inventories is needed which again can be achieved through network centralization. In both occasions, the desired centralization strategy is coupled up with the use of faster transportations to avoid the increase of lead times and the resulting negative side effects of this, which are due to extended transportation distances. Correspondingly, as the effect of the drivers decrease the design trajectories are the same but in the opposite direction. (Lovell et al. 2005, pp. 151)

### 3.5.4 Adding multi-echelon point of view to the framework and network design

Distribution systems, especially in global context, often consist of several stockholding points that locate at different levels in the network. Therefore, it is important to be aware of this multi-echelon side of network design too. de Leeuw et al. (1999, pp. 97-112) have investigated this and based on their findings formed a decision tool, with which it is possible to designate the most suitable network configuration along with control techniques for each case based on a set of distribution characteristic. The fruits of their work are elucidated in the following Table 5, with a pinch of modification making it more suitable for network design study needs.

**Table 5. Distribution characteristics and their influence on multi-echelon network design and control techniques**

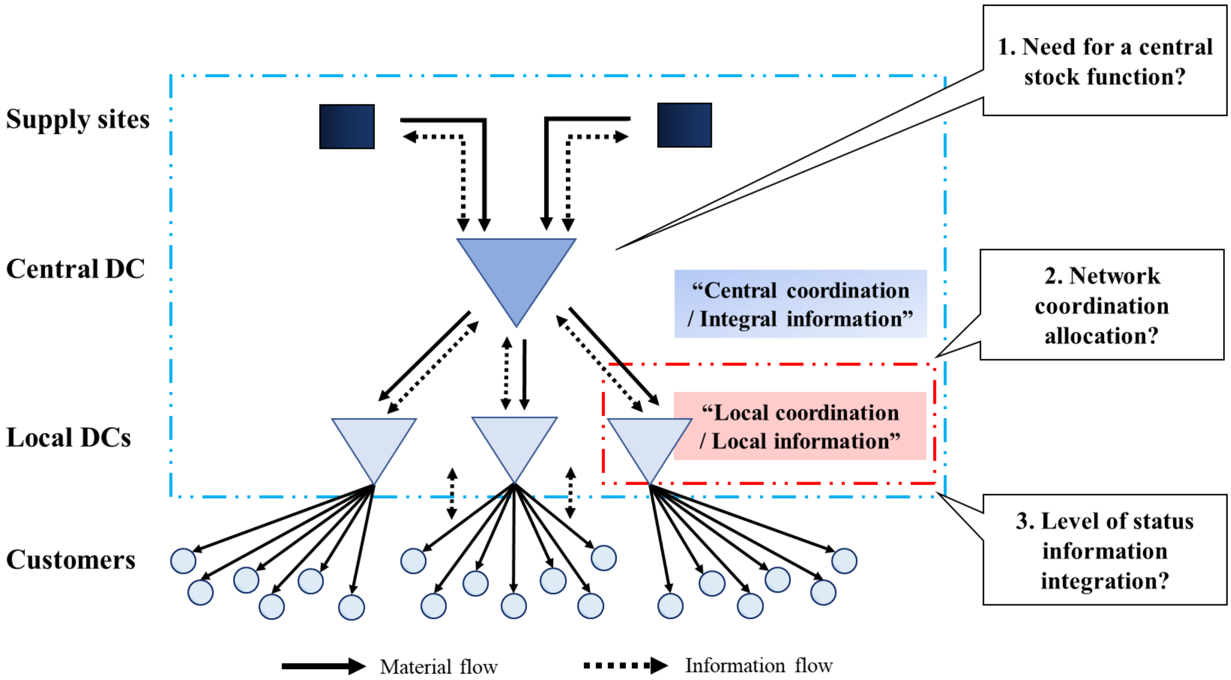
| | Distribution characteristics | 1. Need for a central stock function | 2. Network coordination allocation | 3. Status information |
|---|---|---|---|---|
| *Products* | High value density | Yes | | Integral |
| | High obsolescence risk | Yes | | Integral |
| | Unique products | No | | |
| | Large number of SKUs | | Local | |
| | High product volumes | No | | Integral |
| *Markets* | High customer service required | Yes | Central | |
| | High demand uncertainty | Yes | Local | Local |
| | Large distribution batch sizes | | Central | Local |
| | Seasonal demand | Yes | | |
| *Processes* | Large amount of local DCs | Yes | Local | |
| | Restricted local storage space | Yes | Local | |
| | Long supply lead times | Yes | Local<br>*(if no central stock)* | |
| | High supply frequency | No | | |
| | Promotional action sales period | Yes | Central | |

(adapted from de Leeuw et al. 1999, pp. 110)

As can be seen from the table, the decision tool consists of following aspects, through which the distribution characteristics are reviewed to dictate the most suitable design and control options for the network:

1. *The central stock aspect*, which is concerned with the question of whether a central stock function (central DC) along with local sites (local DCs) is needed in a distribution network for storing the replenishment items and hence facilitating replenishment processes, or is direct supplying from supply sites sufficient enough. (de Leeuw 1999, pp. 100)
2. *The network coordination allocation aspect*, which is concerned with the degree of centralized control applied in the network. Here the options are either to lean on a central coordination ergo push-based scheme, where the decisions about replenishments and other product movement are made solely by a central department; or a local coordination ergo pull-based scheme, where local sites are responsible for their own materials management by ordering goods from supply sites on their own initiative. (de Leeuw 1999, pp. 101)
3. *The status information aspect*, which is concerned with the level of integration of both demand and stock information needed to manage and coordinate replenishments effectively. Here the options are either to control the system using integral “network level” information or local “depot level” information. (de Leeuw 1999, pp. 99)

From the viewpoint of network design, the most interesting aspect in this scheme is the question of whether to include a central stock function in the distribution structure or not. Also, the other aspects considering how to organize and control the material flows are somewhat crucial for achieving efficiency and effectiveness in distribution operations. Following Figure 17 strives to exemplify these aspects and related decisions in terms of distribution network design.




(adapted from de Leeuw 1999, pp. 97-112)

**Figure 17. Design and coordination decisions considering a multi-echelon distribution system**

# 4 SPARE PARTS BUSINESS FROM THE VIEWPOINT OF SUPPLY CHAIN MANAGEMENT

After-sales and spare parts business is an ever-largening area of industrial business. Companies, who have originally been pure capital goods manufacturers, have found opportunities to provide revenue and profit in the after-sales and spares markets. At the same time, the service business is considered as the main driver to enhance customer satisfaction and generate repurchase opportunities. Thus, this has become one of the key areas for future competition. (Deloitte 2013, pp. 2-3)

The aim of after-sales service is to extend the lifetime of capital goods by providing maintenance parts and services to react to immediate failures and in the best case preventing breakdowns from occurring in the first place. From the logistics point of view this aftermarket industry is, though, not the easiest possible due to challenges stemming from the unique nature of the business. Therefore, companies operating in this industry need continuously to be on their guard to be able to create value for both customers and shareholders. (Gebauer et al. 2011, pp. 751) Next, we will dig into these challenges that the spare parts business poses to supply chain management and how to tackle them in terms of distribution network design to meet the service requirements cost-effectively.

## 4.1 Challenges that spare parts business pose to supply chain management

Supply chain management in the context of spare parts tend to be much more complicated than that of finished products. This complexity is stemming from the unique characteristics of spares, which pose challenges to parts planning, warehousing, replacing and transportation among other functions. (Deloitte 2013, pp. 4) There are several contributing factors, but the most critical characteristics affecting especially to network design are collated in Figure 18 and debated on briefly in sections below.

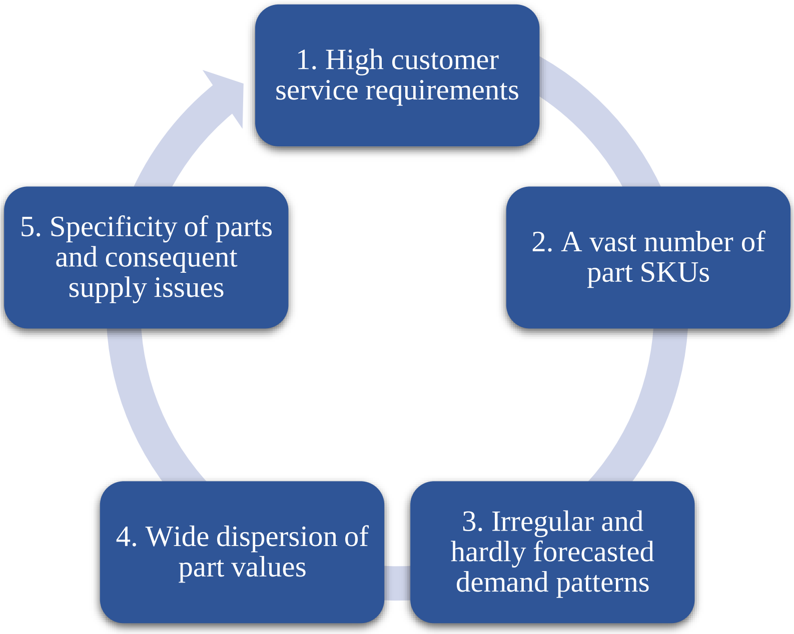



**Figure 18. Collation of spares parts characteristics affecting supply chain management and network design**

1. *High customer service requirements* – Spare parts are usually subject to extremely high service level requirements. For instance, in automotive industry which is referred as the trailblazer of spare parts business, the facing fill rates (i.e. Service Level per cycle) are on world average at 95%, which means that 95 times out of 100 order lines can be fulfilled by the facing warehouse. This is because spare parts tend to be critical to customers' processes and thus the consequences of stockouts can be financially remarkable. On part level this criticality is measured through the effects caused by the failure of the part in case of replacement is not readily available. From the logistics point of view the most significant aspect of this criticality is the time available to react to the need. In terms of this there are often two extremities: whether the need is immediate or there is some leeway. This consequently dictates the required service level in terms of availability as well as sets the boundaries to network design. For instance, in the case of immediate part need local stocking with substantial safety stocks tend to be the only way to proceed, but if there is more time to operate a more centralized network structure combined with direct deliveries becomes also an option. (Deloitte 2013, pp. 5; Huiskonen 2001, pp. 129)

2. *A vast number of part SKUs* – A stock keeping unit (SKU) refers to a unique item kept in stock. The spare parts business is characterized as involving a huge number of different part types, which also tend to come in a variety of shapes and sizes. Hence it is self-evident that the total number of SKUs is huge. According to surveys most original equipment manufacturers (OEMs) can have up to 30 000 stockable part SKUs. This naturally poses great challenges for efficient and effective materials management. In most cases part categorization is needed to create control groups to keep things simple and to focus both coordination efforts and management resources. (Deloitte 2013, pp. 13; Jonsson 2008, pp. 51; Paakki et al. 2011, pp. 164)
3. *Irregular and hardly forecasted demand patterns* – A demand pattern encases both volume and variability aspects of demand for the item under review. When it comes to spare parts business, it is somewhat specific that there is usually a significant amount of parts that have relatively low and sporadic demand. This characteristic is challenging and is making both the design and control of a spare parts distribution network difficult as spare parts are principally make-to-stock (MTS) products. Combined with other characteristics such as above mentioned high criticality, this tends to result in increased amount of safety stocking (preferably close to customers) to cover the unpredictable situations and ensure responsiveness. This however is at odds with the design policies suggested previously, which prompted that low volume and/or unpredictable products should be aggregated and stored centrally to avoid excessive stockholding. (Huiskonen 2001, pp. 130)
4. *Wide dispersion of part values* – It is not uncommon that values of spare parts vary remarkably from very low valued items like fuses to high valued PCB boards and other electronic parts. This naturally causes challenges for stockholding and transportation. This is because high value drives chains to seek solutions that minimize stockholding, but on the other hand low value items require efficient replenishment arrangements so that both the transportation costs and the system and administration costs do not increase unreasonably relative to the part value. The natural solution would be to position the high value items backward in the distribution chain to avoid high inventory values and excess stock while keeping the low value items close to customers, but often this is not possible due to the criticality of the parts and consequent high service level requirements. Therefore, other

means must be found to moderate both logistics costs and tied-up capital while ensuring required customer responsiveness. (Huiskonen 2001, pp. 130; Paakki et al. 2011, pp. 167)

5. *Specificity of parts and consequent supply issues* – Among the wide spectrum of spare parts, there are typically both standard parts and more specific parts. Standard or commercial parts are common materials like batteries, cables and light bulbs that are widely used across all industries. For standard parts there are often several suppliers in the market and hence the availability tends to be good and supply lead times short. On the contrary, specific parts consist of materials which are more industry or even equipment specific like power supplies, mother boards and different sensors, and hence have more limited customer base. Hence there tend to be only a few possible suppliers and in some cases the parts are even produced on a made-to-order (MTO) base. Thus, for specific parts the supply lead times are usually longer and there might even be availability risks. This poses challenges for inventory replenishment and often forces to hold excessive safety stocks. (Huiskonen 2001, pp. 129; Paakki et al. 2011, pp. 167)

## 4.2 The most typical network alternatives for spare parts distribution

As was mentioned earlier, after-sales and spare parts business aims at creating value for customers and shareholders by providing parts and maintenance service to react to immediate breakdowns and in the best case preventing these from occurring in the first place. When it comes to logistics operations and network designing, this should be the starting point when establishing supply chain strategy and network structures. Due to the features described above, a pivotal dilemma for every OEM in the parts business is, however, *"how to establish an appropriate network structure that can provide the needed service level with an optimal balance between costs and tied-up capital"*. (Gebauer et al. 2011, pp. 751)

As the strategic importance of spare parts business for capital goods manufacturers is constantly increasing, the network modeling issue has begun to attract more and more both researchers and industry practitioners. Based on the surveys done by Deloitte (2013, pp. 1-24) and Gebauer et al. (2011, pp. 748-768) there seems to be two alternative directions in use to approach this pivotal dilemma. These have similar features for instance in terms of outsourcing as this is a common practice among OEMs and majority of them are using 3PL services, but the network structures and so distribution operations are different. The alternatives are:

A) *Multi-echelon distribution system with central stock function* – Since the parts business requires high service levels, most OEMs have adopted a multi-echelon network for spare parts distribution. According to surveys, the most common option is that of a two-echelon structure, which consists of supply sites, a central stockholding point (RDC) and a set of local sites (NDC/LDC), which number ranges from 4-18. Here the supply sites supply the central warehouse, that consequently replenishes the local sites, which face the customer demand. In this system, parts can alike be supplied from the central warehouse if they are not available locally. When it comes to the transportation implementation, often both line-haul and delivery transportations are outsourced to 3PLs. By operating with capable 3PLs, OEMs have strong control and visibility with regard to logistics operations, and the efficiency and quality of transportation can be guaranteed. This also tends to improve the overall service ability remarkably. (Deloitte 2013, pp. 10, 17; Gebauer et al. 2011, pp. 755)

B) *Direct supply distribution system* – A minority of OEMs have chosen an opposite direction with a direct supply system. Here the centralized supply sites either directly deliver shipments to customers or in terms of a more wide-spread distribution area supply local sites (NDC/LDC), which then face the end demand. Regardless which one of the two is the case, this rather straightforward structural alternative relies heavily on transit and in this way strives to minimize stockholding points in the network. However, due to the decentralized nature and hence increased distances, the system usually needs to some extent the use of faster transportations to offset the formed intervals. As in the previous alternative, most OEMs counting on this direct supply distribution system have outsourced their transportation operations to 3PLs in quest of achieving both efficiency and effectiveness in transit. (Deloitte 2013, pp. 10, 17; Gebauer et al. 2011, pp. 755)

There may be many opinions which one of these alternatives is more appropriate for spare parts distribution. The answer depends on occasion and is a sum of several things. To give at least some implication of the generic impacts of these approaches on the parts business, the advantages and disadvantages of both alternatives are summarized in Table 6 below in terms of spares distribution.

**Table 6. Summarization of advantages and disadvantages of the approaches generally used in spare parts distribution**

| | A) Multi-echelon distribution system with central stock function | B) Direct supply distribution system |
|---|---|---|
| *Advantages* | + More intricate inventory system with an emphasis on bridging distribution gaps between suppliers and customers by bringing the supply site(s) closer to markets<br>+ Higher product availability across the distribution area<br>+ Shorter lead times<br>+ Higher responsiveness<br>+ Lower transportation costs<br>+ Presumably lower amount of capital employed into the network (*)<br>+ More possibilities for internally tailored supply chain solutions | + More straightforward inventory system with an emphasis on bridging distribution gaps between suppliers and customers by storing sufficient quantities of products close to customers<br>+ Simpler parts planning and coordination of logistics operations<br>+ Lower warehousing, storage and system and administration costs<br>+ Moderate total logistics costs |
| *Disadvantages* | – Higher warehousing, storage and system and administration costs<br>– Challenges with parts planning and logistics operations due to the excessive number of sites<br>– Elevated total logistics costs | – Great dependence on the success of transits<br>– Higher transportation costs due to extensive distances<br>– Longer lead times<br>– Higher risk of inventory stockouts<br>– Vulnerability on slower response to customer demand<br>– Presumably larger amount of capital employed into the network (*) |
| | (*) *The amount of capital employed into inventories and eventually to the distribution network is highly dependent on customer requirements, replenishment options as well as inventory planning* | |

(Deloitte 2013, pp. 10; Gebauer et al. 2011, pp. 755)

# 5 CONDUCTING STRATEGIC NETWORK DESIGN AND ANALYSIS

As a research field strategic network design is an important yet underserved niche within the wide area of logistics and supply chain management research. Most publications discuss the subject only on a high-level and as a result many, especially smaller companies struggle with their supply chains in this globalizing and ever-changing business environment. (Watson et al. 2013, pp. xvi) At the same time, the growth of global markets, rising costs, increasing customer expectations and more intensive competitive pressures are driving the development of more and more complex network designs. The increasing complexity is why supply chain networks, in particularly in the context of global distribution, should frequently be re-evaluated. (Pickett 2013, pp. 30) In the following chapter this inscrutable world of strategic network design will be covered in more detail considering first strategic network design as a research method and then debating on how to complete a full-scale network design study and related analyses step by step.

## 5.1 Strategic network design and analysis as a research method

Strategic network design or sometimes referred as network modeling is part of companies' strategic planning process where strategic objectives, different policies and resource requirements concerning supply chain are determined taking into account all predictable changes in requirements in which timing can be anticipated. (Pickett 2013, pp. 32) At the heart of network modeling is defining the best supply chain structure to physically move products from the source of origin to the final point of consumption. This is done by selecting the right number, location and size of stockholding points and production facilities. At the same time, companies will need to determine the territories of each site, which product should be made or sourced where and how products should flow within the network. (Watson et al. 2013, pp. 1)

Typically, these studies do not produce a single correct answer. Instead, a strategic network design study requires constructing a model from the supply chain network, calculating or using optimization engines to sort through inputs to produce different scenarios, and then analyzing the results of alternative solutions to come up with an optimal solution to support decision making. (Watson et al. 2013, pp. 1) The true value of network design studies is the knowledge gained from understanding the workings of a company's supply chain system and applying imagination to the model in ways that will benefit the network and make executives feel confident that they are making good strategic plans for the future. (Pickett 2013, pp. 38; Watson et al. 2013, pp. 80)

Network design studies typically follow *major changes in business* such as an acquisition or merger, *a change in business strategy* such as a quest for new markets or intended change in the way a firm brings their products to markets, or at the latest *the passage of time* when there arises a need to review whether the network still meets the business requirements or not (Pickett 2013, pp. 32). A strengthening opinion among experts is, however, that these studies should become a more condensed part of supply chain development and be done more frequently. This is because business demographics and characteristics are changing faster than ever which drives the need to re-evaluate networks regularly to keep up with the changes. (Watson et al. 2013, pp. 5)

Generally, there are three possible ways to perform a network design study, which differ in their characteristics and requirements from each other. The available methods are *comparative calculations*, *optimization* and *simulation*:

- *Comparative calculations* are as the name already suggest contrastive calculations between different scenario alternatives chosen by experts. The scenarios are based upon collected data set, assumptions and provided parameters from which first a baseline model and then a collection of alternative what-if scenarios are derived. Therefore, the method is reliant on the quality of the data and parameters as well as the experience of the team performing the modeling analysis. As a result, combined with diligent analyzing and decision making, both a solid and robust network solution is provided. (Course CS20A0050 Toimitusketjun hallinta 2014-2015)
- *Optimization models* are like comparative calculations, but with more complexity and sophistication involved. They are typically linear or mixed integer programs that can determine an "optimal" network design based upon the data, assumptions and parameters

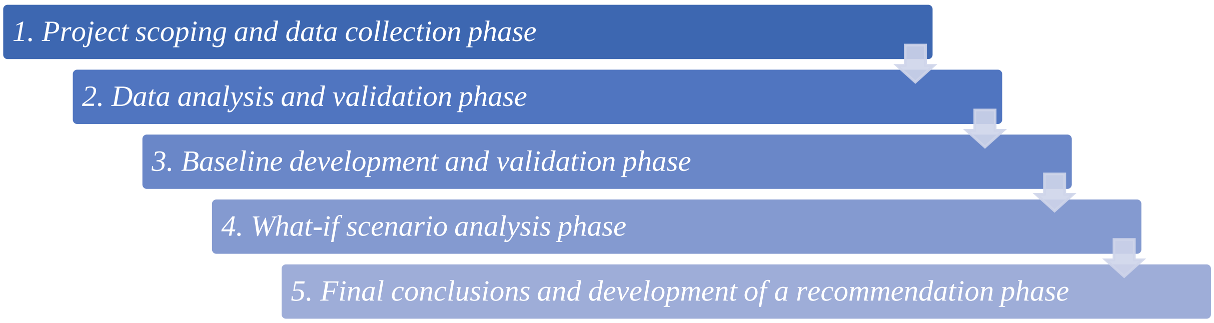
provided. The optimization engines are often very dependent on the inputs and related accuracy. Therefore, changes to any of the assumptions, parameters or data will cause the model to yield a different result. (Pickett 2013, pp. 39)

- *Simulation models*, unlike the previous, will start with a single network alternative and examine the impacts of various kinds of data sets on the scenario over time. Therefore, simulation models are useful for determining and representing the impacts of volatility and network constraints that a company faces in the real world. Like optimization engines, a simulation tool is very dependent on the quality of the input data as well as the skills of the modeler. (Pickett 2013, pp. 39)

To determine which method is right for one's network design project, the designated team needs to decide how important it is to include complex inputs and variables or if averages and assumptions can provide sufficient tools for decision making. (Pickett 2013, pp. 39) In the next chapter, we will look more closely how to actually complete a network design study and which steps are included in this project.

## 5.2 Steps to complete a network design study

To get a strategic network design study done, one should treat it as a scheme and manage like any other complex project within a company. According to Watson et al. (2013, pp. 261) every network design related project can roughly be broken into five main steps or phases, each of which having its own specific purpose considering the entity. These generic steps are depicted in Figure 19 below:




(Watson et al. 2013, pp. 261)

**Figure 19. Steps to complete a network design study**

So, each step has its own function and therefore it is vital that the designated project team goes through each one of them, irrespective of the complexity of the supply chain being analyzed or the amount of time available to complete the study. (Watson et al. 2013, pp. 261) Next, we will go through these steps in more detail in order to be aware of what the network design project encases.

### 5.2.1 Step 1: Project scoping and data collection

Network design studies are often comprehensive projects and they span many different departments within an organization including *sales, operations, logistics, finance* and *IT*. (Watson et al. 2013, pp. 19) This is why, it is important to kick-start the project with a proper scoping session with key stakeholders, where the supply chain and associated parts of it that may be impacted are discussed along with research questions and output expectations of the study. This may seem somewhat trivial, but it is critical that all stakeholders agree to the scope and the questions that the study strives to answer from the start, because these will shape the rest of the project. (Watson et al. 2013, pp. 218, 262)

After the scope and questions are debated on, then the designated project team can start working on the study. The initial step is to acquire all the data needed for the study. This can often be very time-consuming and somewhat frustrating, but proper planning helps here. Before starting the actual collection process, the team is advised to come up with a list of all required data along with what systems or third-party sources the data will come from as well as what would be the most appropriate level of aggregation. (Watson et al. 2013, pp. 262-263) Based on the experiences of Chopra & Meindl (2013, pp. 128-129), Watson et al. (2013, pp. 264-265) and Pickett (2013, pp. 35-36), the following data set listed in Table 7 below should ideally be available when conducting network design studies and building related models.

When collecting the data, it is important to ensure that it is accurate enough. Typically, there are negative impacts and eventually costs involved if the initial data set is in poor condition. (Pickett 2013, pp. 36) Here, a somewhat “rule of thumb” is that one should strive that the data accuracy would be within 1% to 10% of the actual. However, this depends largely on the importance of the project and the culture of the company. (Watson et al. 2013, pp. 140)

**Table 7. Data needs of a network design study**

| Group | Data |
|---|---|
| *Location data* | • Location of current and potential sites<br>• Location of supply sources and production plants<br>• Location of markets and customers |
| *Volumes and material flows* | • Total demand and demand forecasts by regions and SKUs<br>• Total outbound and inbound volumes by each line, mode and node<br>• Total inventory levels by sites and SKUs |
| *Cost and price data* | • Transportation costs between each pair of sites along with related freight rate cards by modes<br>• Inventory costs by sites and as a function of quantity<br>• Facility, labor and material costs by sites<br>• Taxes and customs duties<br>• Exchange rates and their changes within the service area<br>• Products' sales prices in each region |
| *Service level data* | • Desired response time, product availability and delivery reliability among other service ability related factors |
| *General data* | • SKU listing and related material details<br>    ○ Physical size and weight, specificity, source of origin and supply lead times among other things<br>• Facility characteristics<br>    ○ Lease/own, size, capacity, staff and equipment within<br>• Fleet characteristics<br>    ○ Lease/own, capacity and staff<br>• Transportation lead times<br>• Possible supply chain performance reports |

### 5.2.2 Step 2: Data analysis and validation phase

After the team has collected the data, it is important to analyze and understand it to ensure that the data is clean and represents accurately the way the supply chain operates. This phase usually includes a combination of the following activities: *data cleansing*, *data analysis*, *data validation* and *data aggregation*. (Watson et al. 2013, pp. 264)

The process starts with *data cleansing* where the team reviews the data and fixes obvious issues and quality deviations, which might hinder the outcome of the study. Here examples include: order or shipment data with invalid origins or destinations, shipment data with missing/invalid weights or costs and warehouse data with missing/invalid stock levels or SKU data, among other things. (Watson et al. 2013, pp. 264) After the cleansing has been completed, the next step is to *start to analyze the data as whole to understand how the supply chain is operating and materials are flowing within it*. This can be done by creating either summaries or tables that present data so that it can be evaluated, and the underlying supply chain portrayed. (Watson et al. 2013, pp. 264-265) After the data has been analyzed and summaries composed, the next step is to *validate the data with appropriate stakeholders*. This step is a somewhat crucial stage in the project because it ensures that the information to be used has been approved by the appropriate owners of it as well as it gets people from all parts of the organization engaged in the project so that when the final results and recommendations are presented, they are more likely to feel comfortable with these. The steps around cleansing, analysis and validation are usually needed to be iterated until the stakeholders overseeing the appropriate functions feel comfortable that the data to be used reflects their supply chain in a valid way. (Watson et al. 2013, pp. 265)

After the data has been validated and approved, the final step in this phase is to *start aggregating the data for the purposes of modeling* (Watson et al. 2013, pp. 266). This is an important aspect in the network design project, because for example when conducting a global distribution network study, instead of depicting every single customer location the model may aggregate all the customers in one country to a single point, thus keeping the model nice and simple (Watson et al. 2013, pp. 240). Considering modeling, the most important aggregation decisions are usually made around the time period to be used in the study (the most common time frame in network design studies is a year) and when mapping customers into relevant customer groups according to their geographic proximity and type as well as putting products into appropriate product groups based on their source and logistics characteristics. Also, different cost types and sites can be aggregated if needed. (Watson et al. 2013, pp. 237-259) The level of aggregation and the method to be used in this are largely dependent on the scope of the study and the quality of the data, but Watson et al.'s general recommendation (2013, pp. 240, 249) is that it is wiser to start with a few basic aggregation groups and to add then gradually more groups as needed.

As was noted, with a proper aggregation strategy, one can achieve in much more straightforward manner the same level of accuracy and validity in the analysis as one would get when modeling without aggregation (Watson et al. 2013, pp. 256). There are, though, several other reasons why data aggregation is relevant in network design studies and modeling in general. These reasons can be divided into technical and practical reasons as shown in Table 8 below:

**Table 8. Reasons why data aggregation is needed in network modeling**

| | | | |
|---|---|---|---|
| **Technical reasons** | *Computing power* | i. | If all products, sites, customers and vendors are loaded into a single optimization model, one will likely end up with a model that does not fit into specifications of even the most powerful computers and therefore has no chance of solving it in reasonable time. |
| | *Accuracy of forecast* | ii. | Normally, the forecasts for individual products or sites are not even close to accurate (especially those a year out) and therefore it is not reasonable to model data at very detailed level. |
| **Practical reasons** | *Limited resources* | iii. | Often the resources allocated to the project are limited and therefore it is not reasonable from either time or cost viewpoint to cover all possible data on the model. |
| | *Understanding the big picture* | iv. | It can be complicated or almost impossible to understand the big picture and related interactions between different data elements if the model is too detailed. |
| | *Decision making* | v. | Aggregation is necessary for decision makers to get a holistic view of the supply chain subject to the decision making. |

(Watson et al. 2013, pp. 238)

### 5.2.3 Step 3: Baseline development and validation phase

After the project team has analyzed, validated and aggregated the data, it is time to start building the actual supply chain models. The goal of most network design projects is to improve an existing supply chain. To do so and get a chance to compare the costs and service parameters of the what-if scenarios with the existing ones, one needs a baseline model. This is the so-called as-is state or the current state representing how the supply chain is operating. (Watson et al. 2013, pp. 139, 266)

It is possible to divide the baseline into two different but equally important models, which are *an actual baseline* and *an optimized baseline*. *The actual baseline* is an exact representation of the supply chain and how it operated in the past. This presents the existing facilities and their current assignments to customers with flows from each facility to each customer as they happened. This in itself usually raises a set of grievances about the current structure and how material flows within it to be addressed in subsequent scenarios. (Watson et al. 2013, pp. 139-140) After the actual baseline is covered, one will also want to replicate what should have happened based on the business rules in place if everything had gone according to plan. This version of the baseline model is called *the optimized baseline*, which acts as a cleaned-up version the actual baseline. Besides identifying areas for improvement, this model also serves as a valid starting point for the upcoming what-if scenarios as well as provides a fair benchmark to compare these and their results with the existing structure. (Watson et al. 2013, pp. 142-143)

### 5.2.4 Step 4: What-if scenario analysis phase

After the project team has modeled the baselines, they are finally ready to start developing the what-if scenarios. This phase represents the so-called "fun part" of the study, where focus is in ensuring that all the appointed research questions get answered. So, before starting to think over any future scenarios, it is wise to review these questions along with the underlying objectives of the project. After this, the team is advised to start brainstorming and try to develop a sufficient set of alternative scenarios that would make sense to run in order to address the key questions. (Watson et al. 2013, pp. 268) The typical inputs used to derive these different scenarios are future requirements, customer service surveys, database analyses and possible site visits. (Pickett 2013, pp. 37)

The art of what-if scenario analysis and related modeling is that one can freely test different ideas, data sets and strategies as well as include things in the models that do not exist in the current state. In this way, the team gains a deeper understanding about the supply chain network and gets better prepared for future requirements and possibilities. (Watson et al. 2013, pp. 224-225) This, though, requires that the models should be able to capture the important aspects of the problem and do not get bogged in trivial. To success in this and get the phase effectively done, it is recommended to start with simple models and incrementally create ever more complex ones using an iterative approach. (Watson et al. 2013, pp. 222-223)

To be able to answer the research questions in the best possible way, the team should also address a set of different what-if questions. A network design project might have several what-if questions, but according to Watson et al. (2013, pp. 268) the three most basic ones are:

1. *What if we picked a different set or number of facilities?*
2. *What if demand was higher, what if it was lower?*
3. *What if our projected costs were higher, what if they were lower?*

The idea of these questions is to raise additional thoughts about the supply chain's design and its configuration. The questions usually also bring up a need for some additional analyses when the top scenario candidates are found. Considering the big picture, often the most important of these supplements is:

- *Sensitivity analysis*, which is based on the idea of setting up runs that fluctuate the key variables to test the robustness of the network solution. In network design studies the most important inputs are usually demand and transportation costs that are prone to uncertainty or have potential to change over time. By modifying these variables on one-at-a-time (OAT) basis keeping everything else unchanged, the effects on the entirety can be unambiguously determined. (Pickett 2013, pp. 38; Watson et al. 2013, pp. 77)

All the above described lead eventually to the ultimate goal of what-if scenario analyzing, which is to come up with a both solid and robust solution, that maximizes return on investment while delivering improved customer service, inventory control and transportation performance. (Pickett 2013, pp. 35; Watson et al. 2013, pp. 268) It is also crucial that the analyses provide a sound basis to make it possible to explain the solution and the underlying factors driving this to people who are not familiar with the model or network modeling, in a concise and understandable manner. (Watson et al. 2013, pp. 268-289)

### 5.2.5 Step 5: Final conclusions and development of a recommendation phase

After the project team has run a sufficient number of scenarios, tested and analyzed different alternatives, and finally understands the best solution and what is driving this, it is time to compile the results along with supporting discussions and conclusions for presenting to the management team. Even though it may sound weird, this is often the most crucial part of the entire project, because in this phase the outcomes of the project are sold to executives. Thus, this phase should be given proper attention. (Watson et al. 2013, pp. 269-270)

When making decisions, it is important to keep in mind that a network model is by its definition meant to be only a representation of a real entity. No matter how detailed or precise a model is, it can never represent reality entirely. All network models are based on the best available data and thus will have some degree of assumptions and simplified rules. Therefore, one should also consider other aspects affecting the outcome. These include *effects on customer service and perception*, *impacts on the daily operation* as well as *complexity of implementation* among other things. It is also good to notice that network modeling is designed only to provide decision support and is not a substitute to judgment and due diligence. (Watson et al. 2013, pp. 18, 226)

# 6 RESEARCH PROCESS AND METHODOLOGY

To conduct the research in question, a theory-based problem-solving and modeling study was carried out. The study itself was very multifaceted and practical, and involved building a modeling tool based on the literature findings presented earlier. This tool was then capitalized to model and test different scenario alternatives and eventually solve the global spare parts distribution related logistics problem.

In this chapter, the research process and methods used during this logistics network study are introduced more thoroughly. It is likewise elucidated how the needed data was collected and what kind of presumptions were made during the case study. To cover the valuable business information included in this report, the data had to be understandably encrypted. This process along with the factors related to the interpretation of the results is also slightly opened in the coming chapter.

## 6.1 Research process and methods

The research done was all about spare parts distribution in the ascending APA area and focused on establishing the current state of distribution in this area as well as performing a network analysis of selected distribution scenarios to find out the most profitable and operationally efficient way to distribute spare parts in the area for the future. Hence, the research was fallen in the category of logistics and supply chain development, and was carried out as a strategic distribution network design study. The research process followed to a great extent the Watson et al.'s steps to complete a network design study, which were presented earlier. These created the so-called initial step marks for the research, which were then adapted to be suitable for the case study. As has already been stated the study involved building a modeling tool through which the what-if scenarios were modeled, and related scenario analyses conducted. In this and in the development of the scenarios played a significant role the findings of the literature review. In order to perform the study, also large amount of empirical data was needed, which was collected from various sources as will be seen. The used research process and related methods are elucidated in Figure 20 below.

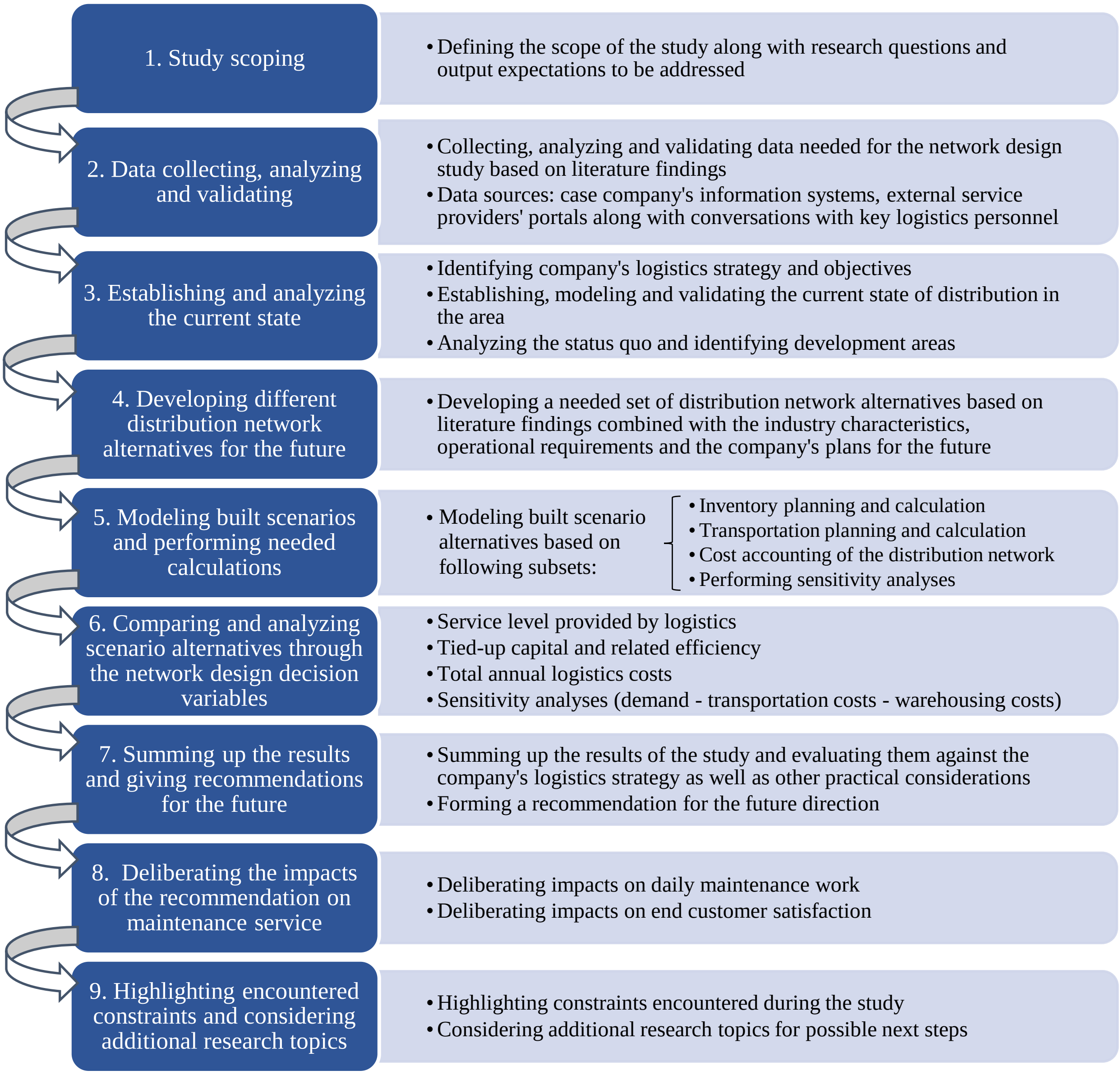



**Figure 20. Research process and methods used in the case study**

*1.* As can be seen, *the study and the whole research process started with* an orientation meeting where the starting point and the scope of the study along with initial objectives and output expectations were debated on with representatives of the case company. Based on this study frame, a set of research questions were derived, which further formatted the study to as a scientific thesis project by linking it to a theoretical background and giving it a research identity. These issues and their inner meaning in terms of the study were covered in more detail in the introduction chapter (Chapter 1) presented earlier.

2. *The second step of the process* was the data collection, analysis and validation phase, which was conducted using the step by step instructions presented in the previous chapter (Chapter 5) and the "data needs of a network design study" collection illustrated in Table 7. The needed data was acquired from the case company's various information systems such as SAP ERP (enterprise resource planning software), Servigistics WMS (warehouse management system) and QlikView BIS (business intelligence system), from the company's centralized intranet, from external service providers' (mainly 3PLs) portals and websites as well as through various discussions with the company's key logistics personnel. Given the scope of the study, the required data (locations, material flows, warehousing, transportation, logistics costs, service level and material details among others) was quite readily available. Also, the needed data aggregations (regarding warehousing and transportations) went well. However, the data base gathering from various of sources, the digestion of the data and the elaboration of this to fit in modeling needs took plenty of time. There were also some complexities in terms of parts' demand and related deviation parameters needed for both demand and inventory planning (for more information see APPENDIX 1). This issue was eventually solved by deriving the demand at SKU level (i.e. item level) from warehouse outbounds and then modifying this monthly data in order to get the needed data elements like annual demand, average demand, demand deviation and the coefficient of variation (CV). As the data had been gathered and analyzed, the last step in this phase was to validate the entire data base, which was done in cooperation with appropriate stakeholders.

3. *The third step of the research process* was establishing and analyzing the as-is state in the form of "Baseline (2017)", which started with summing up the collected data and then modeling it in a way that the current state of distribution could be properly represented. This was aided by visual illustration in the form of "geomapping". An essential part of this current state establishing was also identifying the company's logistics strategy and objectives more thoroughly. Based on the current state analysis some clear development areas were found, which were then further researched and brought in the future scenarios. These issues will be covered in greater detail in the upcoming chapters.

Because the study was focused only on the higher-level global distribution, at this point some alignments had to be, though, made to narrow down the entity to be modeled. Although a distribution chain in real life would include all nodes and routes between the supply-side and the demand-side, in the “Baseline (2017)” and in upcoming what-if scenarios the scheme was consciously abridged. In these, the global distribution centers (EDC and CDC) supplying products to the APA area were regarded as supply sites (= the supply-side) and the receiving frontlines’ national distribution centers or briefer the APA area frontlines’ NDCs were considered as internal customers (= the demand-side), whose distribution activities and the network between these are to be studied in the work. In reality, these frontlines would of course serve various local storages and eventually external customers, but this local side of distribution was not included either in the study or in the models.

4. *The fourth step of the process* was the so-called what-if scenario analysis phase, where different distribution network alternatives for the future were developed based on literature findings combined with the industry characteristics, the recognized operational requirements and the company's intentions for the future. Also, the identified development areas were brought into these scenarios. During this phase four scenario alternatives including the cleaned-up version of the actual baseline, the “Baseline (Optimized)”, were built. To this and the way how these scenarios were developed will be returned in more detail in the later chapters.

5. *The fifth step of the research process* was to model the built what-if scenarios and run all needed calculations. The modeling instrument used in this study was basic Microsoft Excel and hence the whole scenario analysis was done through Excel-based scenario calculations. However, in order to effectively use the limited resources and time allocated to the study, a semi-automated modeling tool was built for the research needs, through which the scenario alternatives could be modeled. This modeling tool consisted of *an inventory module* and *a transportation module*, which synchronously in cooperation performed the needed sub planning and calculations and provided aggregated decision-making data for the summarizing master page. As expected, the tool used the current state data as its foundation and based on given parameters combined with the set materials management settings and policies run the scenario calculations. In addition to

the generic modeling, a sensitivity feature was also included in the tool which allowed performing small-scale sensitivity analyses by altering the key inputs.

Next, the inner life of this modeling tool along with its modules is shortly introduced to give some idea of how the scenario modeling took place with the tool and above all in which way the results of this study have been achieved. For confidential reasons, though, any detailed information about the calculations or data behind these cannot be revealed.

*A.* **Inventory module**

The inventory module of the tool accounted for both inventory planning and materials management of the scenarios and was managed by applying the general inventory planning and management principles summoned in terms of variables in APPENDIX 1 and equations in APPENDIX 2. The inventory planning and hence the modeling in the tool were based on the reorder point planning, which was chosen to be the inventory control method as the case company relies on it at their global distribution centers as well. As for the planning and yet modeling process, it started with these generic variables determined from the previously collected data, with which by using the equations and set materials management settings, a set of inventory control parameters were derived. These along with the current state data base were then used to figuratively set up and manage the inventory networks modeled in each scenario alternative. Given the aforesaid planning policy, the most important parameters needed for this inventory planning and control were the ones depicted in the Table 9 below.

**Table 9. Inventory planning and control parameters used in the modeling tool**

| | | | |
|---|---|---|---|
| *i.* | *Reorder point = ROP* | *iv.* | *Cycle stock = CS* |
| *ii.* | *Economic order quantity = EOQ* | *v.* | *Safety stock = SS* (*) |
| *iii.* | *Annual ordering frequency = n* | *vi.* | *Average inventory = I* |
| *(*) Notice the effect of demand variability on the calculation principle and the equation to be used* | | | |

A fundamental part of inventory planning and management in the modeling tool was likewise spare parts' categorization. The categorization leaned quite heavily on Paakki et al.'s idea (2011, pp. 167-168) of creating a categorization framework by determining and incorporating both *a supply link parameter* and *a demand link parameter*. According to the authors, the supply link between the supply and internal processes aspects consists of sourcing related factors such as availability risk, lead time variance and accuracy of the delivered quantity, from which the most relevant one in each case is chosen to be the parameter. Consequently, the demand link between the internal processes and demand aspects consists of sales related factors from which the most critical ones regarding parts categorization are usually demand variability and material prices. Again, here the most relevant one is chosen to be the parameter. Once the parameters have been agreed upon, then these aspects are combined into a two-dimensional matrix, which eventually will allow the parts categorization to be made.

In the case study and yet in the tool, for the supply link was chosen parts availability risk, which in turn is originating from their specificity. Under this, parts were categorized either as specific parts with higher availability risk [*risk class I*] or standard parts with lower risk [*risk class II*]. For the demand link, a somewhat more traditional way was chosen in the form of an ABC analysis, where the parts were categorized into four categories (*A [≤50%]*, *B [≤80%]*, *C [≤98%]* and *D [≤100%]*) based on their value and importance in terms of generating revenue. Here the category A stood for the most important parts that yielded the highest revenue (up to 50% of total annual revenue) and category D the least important parts generating only 2% of total annual revenue). When these were embedded, a two-dimensional matrix was created. This was then used to assign the facing fill rates (i.e. Service Level per cycle [%]) to each part in each inventory and in this way in the bigger picture manage the SKU base. The facing fill rates were assigned based on the trailblazing automotive industry and its world average rate of 95% with a little twist using the categories as shown in the following Table 10.

**Table 10. Spare parts' categorization in the modeling tool**

| **Combination** (Two-dimensional matrix) | **Supply link** Availability risk classification | **Demand link** ABC classification | **SLc [%]** |
|---|---|---|---|
| *IA* | I | A | **98 %** |
| *IB* | I | B | **96 %** |
| *IC* | I | C | **92 %** |
| *ID* | I | D | **90 %** |
| *IIA* | II | A | **96 %** |
| *IIB* | II | B | **94 %** |
| *IIC* | II | C | **90 %** |
| *IID* | II | D | **88 %** |

The parts were also categorized based on their sources of origin in terms of the supply sites (EDC, CDC and Local) to determine the replenishment lead times and in a bigger picture link warehousing to transportations. As the supply sites were assumed to have the needed parts readily sourced and on hand, the lead times (LT) consisted of internal planning time (PDT) + door-to-door-to-shelf transportation times (GRT). The replenishment lead times used in the scenarios are compiled in APPENDIX 3. However, as the transportation planning and hence replenishments in this modeling tool are largely based on consolidations combined with the parallel multimodal use of transportation modes, as will be seen, the inventory planning had to be conducted through masses in accordance with the prudence principle, which in this context means longer replenishment lengths due to the extensive use of slower yet more cost-effective transportation modes.

As for the warehousing related logistics costs, these were also taken into account in the module. From the cost elements of a distribution network, directly affected by warehousing were inventory holding costs, system and administration costs and storage costs. However, as the case company relies heavily on external service providers (3PLs) in its distribution operations, from the above mentioned only *inventory holding costs* and *system and administration costs* were present in the case. In addition to these, *stockout costs* were also wanted to be highlighted in the scenarios. These costs were considered in the modeling tool in the following way:

*i.* *Inventory holding costs* – Inventory holding costs were calculated in two different ways based on the facility in question. In the frontlines' NDCs, the holding cost was calculated purely as a percentage of the monetary value of inventory per year. The percentage (i) was decided to be 22% based on theoretical reference values and conversations with the company representatives. Here 5% represents the capital cost, 7% the storage cost and 10% the risk cost. However, at central stock functions the holding costs were decided to be calculated as a relative cost based on the actual general ledger data from the fiscal year 2017 in terms of storage costs (rent and material handling), while keeping the capital cost as 5% and the risk cost as 10%. As for the cross-docks, which tend to act a somewhat the same manner as central stock functions but with the main intention to serve as consolidating waypoints, the holding cost was assigned to be 30% of monetary value of inventory due to greater administrative requirements in material flow management.

ii. *System and administration costs / ordering costs* – System and administration costs were generalized to include all ordering related administration costs. Because the ordering processes in the case company are to a large extent automatized, the accumulation of costs is not, though, that much. In the tool, the ordering costs were calculated based on an assumption that a full-time equivalent (FTE) can handle in total 25 000 orders a year against his/her annual salary.

iii. *Annual stockout costs / annual inefficiency costs* – Related more to the distribution network as a whole but with a premise in warehousing, the effects of stockouts were wanted to bring up and present in the form of annual inefficiency costs. The effect of a stockout was approximated in terms of an average cost of lost working time of a technician combined with the average cost of shipping a spare part from the nearest DC to the site via express (which will though be taken into account in transportation planning in the form of an established "fast lane"). Consequently, the probability of a stockout was postulated to be the inverse probability of product availability ergo $P(s) = 1\text{-}SLc$. Although these were just rough generalizations, they seemed to express quite significant cost implications as will be seen.

When the inventory planning and related calculations were completed, the tool gathered the general decision-making data from the scenario to a summarizing master page and completed this by calculating a set of inventory-related key performance indicators. From the viewpoint of warehouse network management, the most interesting factors that were compiled to the master page were *total warehouse operating costs, total capital employed into the network, service levels provided by each stockholding point [SLc], inventory turnover rates [v]* along with *the related executive summaries of the inventories held*.

### *B.* Transportation module

The transportation module of the tool accounted analogously for both transportation planning and management. In the module, transportation needs were divided into line-haul transportations and delivery transportations. Given the scope of the study, in this case the line-haul element is covering all material flow between the supply sites and a possible central stock function and the delivery element all material movement between the central stock function and the APA area frontlines' NDCs. If the modeled scenarios involved direct supplying from the supply site(s), this was considered as delivery transportation as well.

The transportation modeling in the module relied on a general laconism that transportation needs originate from the need to move material within the delivery chain and its nodes, and for each waypoint the total amount of goods inbound will be equal to the total amount of goods outbound. Within this assumption, the model for example insisted that warehouses can neither consume nor produce goods, but merely act as conduits to enable more efficient shipping. The model also assumed that materials flow as in a complete world without any breaks or other problems. When it came to the ground level planning, this in turn was leaned on an idea of expressing and modeling the demand in total not shipment by shipment. The reason for this was that the modeling premise wanted to keep as simple as possible to be able to efficiently manage the data entity and to avoid the tool from becoming either unwieldy or introduce a false sense of accuracy. (Watson et al. 2013, pp. 102; 166)

Based on the aforesaid, the transportation planning process started with the determination of the transportation needs for both line-hauling and delivering. This proceeded by firstly compiling the current state inbound delivery data of the frontlines (the demand-side) and then by complementing this with both sourcing and material data. As a result, the transportation volumes [kg] were managed to be divided into "baskets" based on material origins (the supply-side) of the delivered items. After this was successfully done, the entire delivery chains and eventually the transportation needs could be illustrated and modeled by applying the information on which materials come from where, how much in total each supply site (EDC and CDC) has shipped during the year and what was the total inbound volume to each depot along with the previous reasoning that outbound volumes will match inbound volumes and vice versa. The results of this were then designated to be the premise of transportations needs with the prevailing demand, which could be yet extended in the future scenarios as well.

As for the actual transportation planning and management, in the module line-hauling and delivering were understandably handled differently due to their different meanings and roles in terms of customer value creation. However, as the modeling relied on the power of consolidation along with the parallel multimodal use of transportation modes, the fundamental premises were somewhat the same. The following descriptions will elucidate the used planning and calculation procedures in these cases:

- *Line-haul transportation planning and cost calculation* – In the tool line-haul transportations were planned and calculated by dividing supply sites' total transportation needs during a year to weekly sea freight consolidations and weekly air freight consolidations. Although the shipping frequency is in both cases the same, the difference comes from lead times as well as shipping costs. In order to focus transportation needs to the shipping modes effectively, the Pareto principle was used, which suggests that 80% of the effects tend to come from 20% of the causes. Based on this 80% of the transportation need (representing the mass) was allocated to more cost-effective yet slower sea freight while the remaining 20% (representing the most meaningful parts) were shipped via more responsive but pricier air freight. As for line-haul transportation costs, these were calculated per weekly consolidation consortiums by using the negotiated transportation line-specific weight-based freight rates [XDR/kg].
- *Delivery transportation planning and cost calculation* – In the tool delivery transportations were planned and calculated by dividing the yearly line-specific total delivery needs to weekly and daily consolidations. This division was made because given the specific characteristics of the business and industry, it was considered valuable to establish a kind of "fast lane" for important parts and rush deliveries while also striving for cost-effectiveness. In contrast with line-haul transportation, only the daily consolidation was standardized in terms of shipping condition (express parcel) and the modal choice for weekly transportations was decided on the basis of shipping costs between sea freight, air freight and express parcel (the tool was programmed to choose the most cost-effective way to carry out the transportation need). Regarding to this, a weight-based shipping condition

cost analysis was performed for each possible delivery line to determine the most economical modal choice for each shipment need. In order to focus transportation needs effectively, the Pareto principle was again used. Based on this 80% of the transportation need (representing the mass) was allocated to weekly delivery consolidation while the remaining 20% (representing the most important parts) were shipped on a daily basis via express. As for delivery transportation costs, these were calculated per consolidation consortiums (daily and weekly) by using the rate cards provided by 3PLs. Each rate card had its own calculation procedure with several sub costs, which eventually provided a weight-based freight rate [XDR/kg]. The tool was, though, built in a way that it automatically retrieved the needed data from the rate cards, provided a freight rate according to the shipping details and calculated the transportation cost.

When the transportation planning and related calculations were completed, the tool again gathered the general decision-making data from the scenario to the summarizing master page. From the viewpoint of transportation management, the most interesting factors that were compiled to the master page were *total line-haul transportation costs* and *total delivery transportation costs* along with *the related summaries of transportation volumes and times*.

In order to figuratively close the circle with respect to the modeling tool, Figures 21 and 22 below reflect an image what the tool actually looked like. The former figure illustrates the so-called user interface of the tool in terms of the aforesaid summarizing master page and the materials management setting page. The latter figure consequently illustrates views considering both the inventory and the transportation module along with related calculation sheets in terms of one frontline’s, more precisely AU FL (203), NDC. The figures are actual screenshots from the modeling of the “Baseline (Optimized)” scenario.

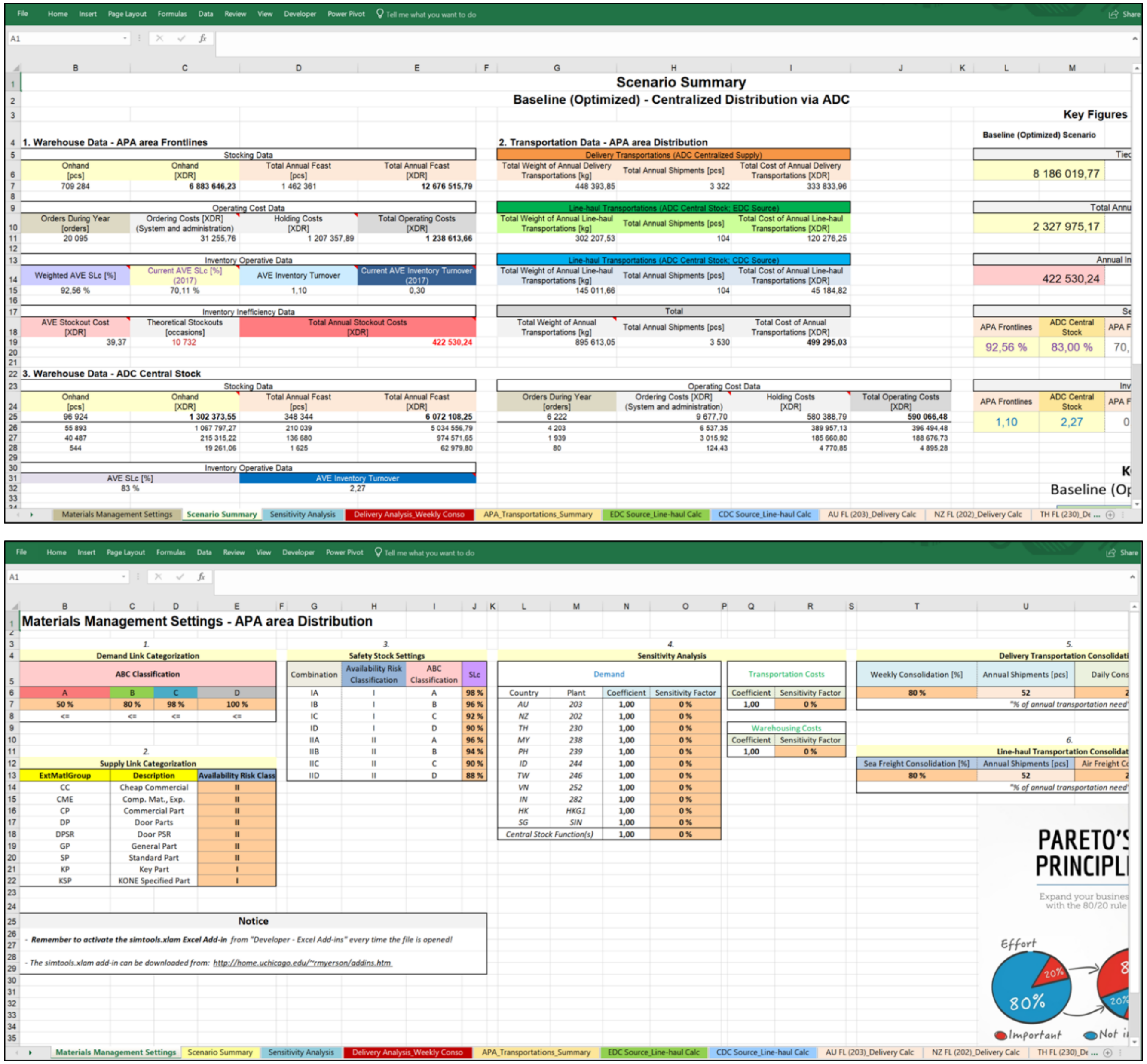
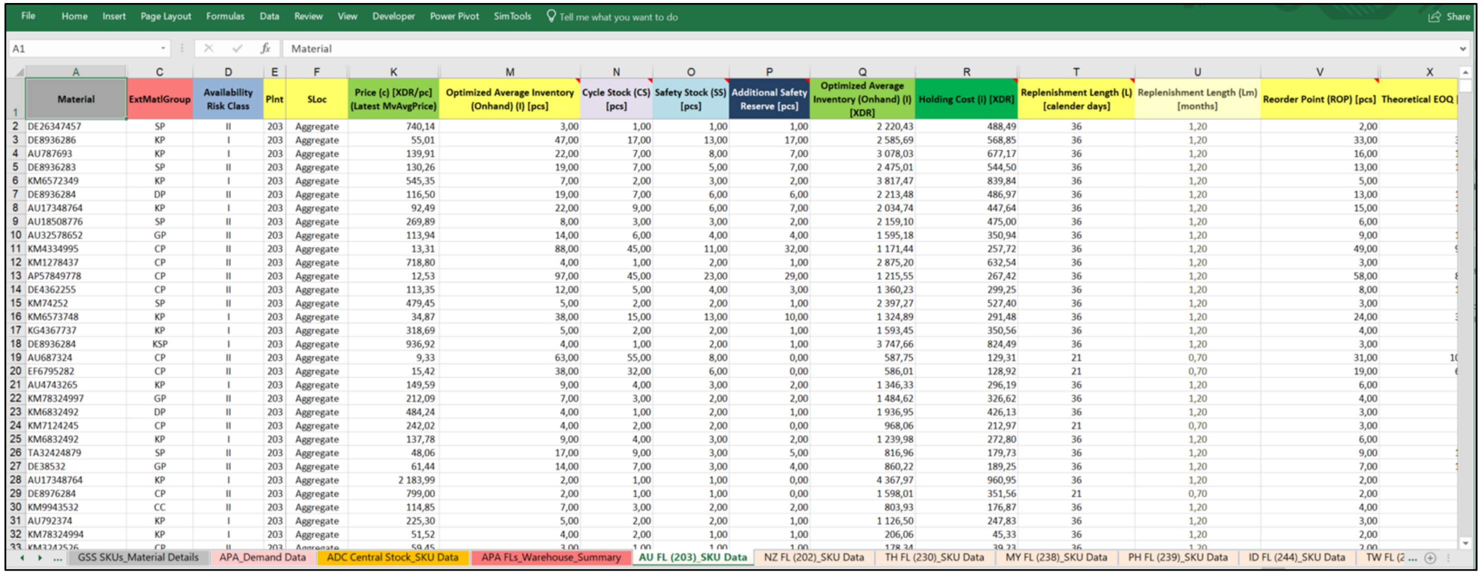
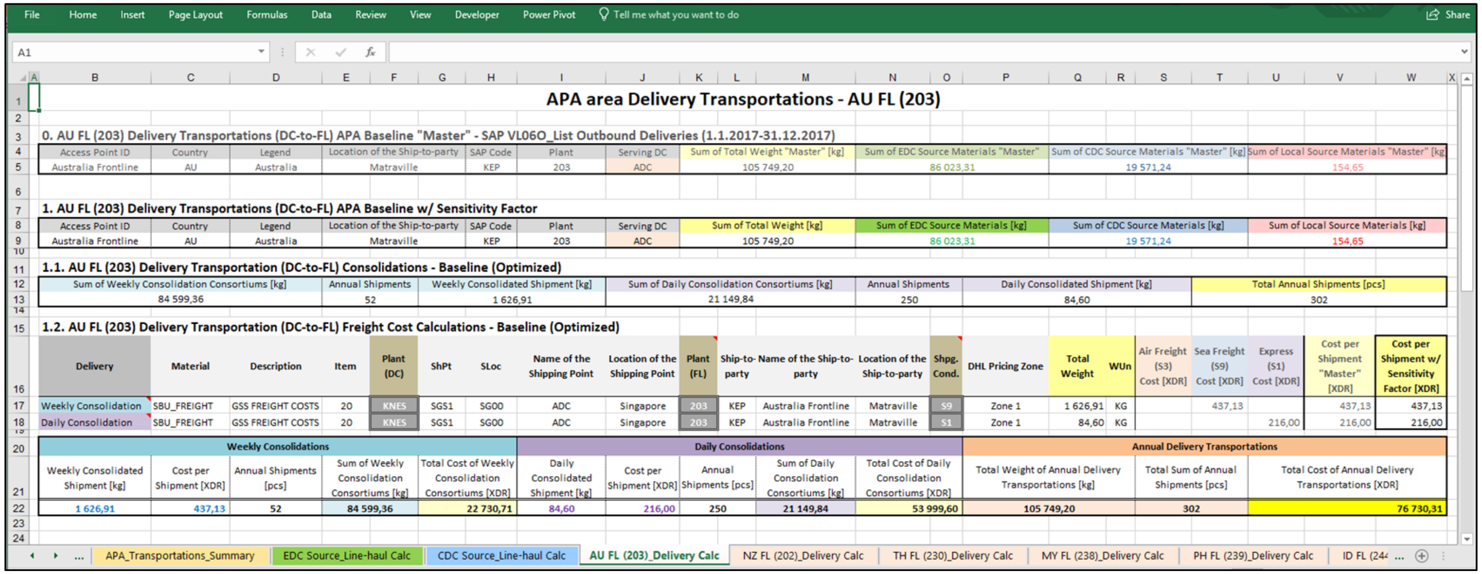



**Figure 21. View of the modeling tool's user interface**



| Material | ExtMatlGroup | Availability Risk Class | Plnt | SLoc | Price (c) [XDR/pc] (Latest MvAvgPrice) | Optimized Average Inventory (Onhand) (I) [pcs] | Cycle Stock (CS) [pcs] | Safety Stock (SS) [pcs] | Additional Safety Reserve [pcs] | Optimized Average Inventory (Onhand) (I) [XDR] | Holding Cost (i) [XDR] | Replenishment Length (L) [calender days] | Replenishment Length (Lm) [months] | Reorder Point (ROP) [pcs] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DE26347457 | SP | II | 203 | Aggregate | 740,14 | 3,00 | 1,00 | 1,00 | 1,00 | 2 220,43 | 488,49 | 36 | 1,20 | 2,00 |
| DE8936286 | KP | I | 203 | Aggregate | 55,01 | 47,00 | 17,00 | 13,00 | 17,00 | 2 585,69 | 568,85 | 36 | 1,20 | 33,00 |
| AU787693 | KP | I | 203 | Aggregate | 139,91 | 22,00 | 7,00 | 8,00 | 7,00 | 3 078,03 | 677,17 | 36 | 1,20 | 16,00 |
| DE8936283 | SP | II | 203 | Aggregate | 130,26 | 19,00 | 7,00 | 5,00 | 7,00 | 2 475,01 | 544,50 | 36 | 1,20 | 13,00 |
| KM6572349 | KP | I | 203 | Aggregate | 545,35 | 7,00 | 2,00 | 3,00 | 2,00 | 3 817,47 | 839,84 | 36 | 1,20 | 5,00 |
| DE8936284 | DP | II | 203 | Aggregate | 116,50 | 19,00 | 7,00 | 6,00 | 6,00 | 2 213,48 | 486,97 | 36 | 1,20 | 13,00 |
| AU17348764 | KP | I | 203 | Aggregate | 92,49 | 22,00 | 9,00 | 6,00 | 7,00 | 2 034,74 | 447,64 | 36 | 1,20 | 15,00 |
| AU18508776 | SP | II | 203 | Aggregate | 269,89 | 8,00 | 3,00 | 3,00 | 2,00 | 2 159,10 | 475,00 | 36 | 1,20 | 6,00 |
| AU32578652 | GP | II | 203 | Aggregate | 113,94 | 14,00 | 6,00 | 4,00 | 4,00 | 1 595,18 | 350,94 | 36 | 1,20 | 9,00 |
| KM4334995 | CP | II | 203 | Aggregate | 13,31 | 88,00 | 45,00 | 11,00 | 32,00 | 1 171,44 | 257,72 | 36 | 1,20 | 49,00 |
| KM1278437 | CP | II | 203 | Aggregate | 718,80 | 4,00 | 1,00 | 2,00 | 1,00 | 2 875,20 | 632,54 | 36 | 1,20 | 3,00 |
| AP57849778 | CP | II | 203 | Aggregate | 12,53 | 97,00 | 45,00 | 23,00 | 29,00 | 1 215,55 | 267,42 | 36 | 1,20 | 58,00 |
| DE4362255 | CP | II | 203 | Aggregate | 113,35 | 12,00 | 5,00 | 4,00 | 3,00 | 1 360,23 | 299,25 | 36 | 1,20 | 8,00 |
| KM74252 | SP | II | 203 | Aggregate | 479,45 | 5,00 | 2,00 | 2,00 | 1,00 | 2 397,27 | 527,40 | 36 | 1,20 | 3,00 |
| KM6573748 | KP | I | 203 | Aggregate | 34,87 | 38,00 | 15,00 | 13,00 | 10,00 | 1 324,89 | 291,48 | 36 | 1,20 | 24,00 |
| KG4367737 | KP | I | 203 | Aggregate | 318,69 | 5,00 | 2,00 | 2,00 | 1,00 | 1 593,45 | 350,56 | 36 | 1,20 | 4,00 |
| DE8936284 | KSP | I | 203 | Aggregate | 936,92 | 4,00 | 1,00 | 2,00 | 1,00 | 3 747,66 | 824,49 | 36 | 1,20 | 3,00 |
| AU687324 | CP | II | 203 | Aggregate | 9,33 | 63,00 | 55,00 | 8,00 | 0,00 | 587,75 | 129,31 | 21 | 0,70 | 31,00 |
| EF6795282 | CP | II | 203 | Aggregate | 15,42 | 38,00 | 32,00 | 6,00 | 0,00 | 586,01 | 128,92 | 21 | 0,70 | 19,00 |
| AU4743265 | KP | I | 203 | Aggregate | 149,59 | 9,00 | 4,00 | 3,00 | 2,00 | 1 346,33 | 296,19 | 36 | 1,20 | 6,00 |
| KM78324997 | GP | II | 203 | Aggregate | 212,09 | 7,00 | 3,00 | 2,00 | 2,00 | 1 484,62 | 326,62 | 36 | 1,20 | 4,00 |
| KM6832492 | DP | II | 203 | Aggregate | 484,24 | 4,00 | 1,00 | 2,00 | 1,00 | 1 936,95 | 426,13 | 36 | 1,20 | 3,00 |
| KM7124245 | CP | II | 203 | Aggregate | 242,02 | 4,00 | 2,00 | 2,00 | 0,00 | 968,06 | 212,97 | 21 | 0,70 | 3,00 |
| KM6832492 | KP | I | 203 | Aggregate | 137,78 | 9,00 | 4,00 | 3,00 | 2,00 | 1 239,98 | 272,80 | 36 | 1,20 | 6,00 |
| TA32424879 | SP | II | 203 | Aggregate | 48,06 | 17,00 | 9,00 | 3,00 | 5,00 | 816,96 | 179,73 | 36 | 1,20 | 9,00 |
| DE38532 | GP | II | 203 | Aggregate | 61,44 | 14,00 | 7,00 | 3,00 | 4,00 | 860,22 | 189,25 | 36 | 1,20 | 7,00 |
| AU17348764 | KP | I | 203 | Aggregate | 2 183,99 | 2,00 | 1,00 | 1,00 | 0,00 | 4 367,97 | 960,95 | 36 | 1,20 | 2,00 |
| DE8976284 | CP | II | 203 | Aggregate | 799,00 | 2,00 | 1,00 | 1,00 | 0,00 | 1 598,01 | 351,56 | 21 | 0,70 | 2,00 |
| KM9943532 | CC | II | 203 | Aggregate | 114,85 | 7,00 | 3,00 | 2,00 | 2,00 | 803,93 | 176,87 | 36 | 1,20 | 4,00 |
| AU792374 | KP | I | 203 | Aggregate | 225,30 | 5,00 | 2,00 | 2,00 | 1,00 | 1 126,50 | 247,83 | 36 | 1,20 | 3,00 |
| KM78324994 | KP | I | 203 | Aggregate | 51,52 | 4,00 | 2,00 | 1,00 | 1,00 | 206,06 | 45,33 | 36 | 1,20 | 2,00 |



**APA area Delivery Transportations - AU FL (203)**

**0. AU FL (203) Delivery Transportations (DC-to-FL) APA Baseline "Master" - SAP VL06O_List Outbound Deliveries (1.1.2017-31.12.2017)**

| Access Point ID | Country | Legend | Location of the Ship-to-party | SAP Code | Plant | Serving DC | Sum of Total Weight "Master" [kg] | Sum of EDC Source Materials "Master" | Sum of CDC Source Materials "Master" [kg] | Sum of Local Source Materials "Master" [kg] |
|---|---|---|---|---|---|---|---|---|---|---|
| Australia Frontline | AU | Australia | Matraville | KEP | 203 | ADC | 105 749,20 | 86 023,31 | 19 571,24 | 154,65 |

**1. AU FL (203) Delivery Transportations (DC-to-FL) APA Baseline w/ Sensitivity Factor**

| Access Point ID | Country | Legend | Location of the Ship-to-party | SAP Code | Plant | Serving DC | Sum of Total Weight [kg] | Sum of EDC Source Materials [kg] | Sum of CDC Source Materials [kg] | Sum of Local Source Materials [kg] |
|---|---|---|---|---|---|---|---|---|---|---|
| Australia Frontline | AU | Australia | Matraville | KEP | 203 | ADC | 105 749,20 | 86 023,31 | 19 571,24 | 154,65 |

**1.1. AU FL (203) Delivery Transportation (DC-to-FL) Consolidations - Baseline (Optimized)**

| Sum of Weekly Consolidation Consortiums [kg] | Annual Shipments | Weekly Consolidated Shipment [kg] | Sum of Daily Consolidation Consortiums [kg] | Annual Shipments | Daily Consolidated Shipment [kg] | Total Annual Shipments [pcs] |
|---|---|---|---|---|---|---|
| 84 599,36 | 52 | 1 626,91 | 21 149,84 | 250 | 84,60 | 302 |

**1.2. AU FL (203) Delivery Transportation (DC-to-FL) Freight Cost Calculations - Baseline (Optimized)**

| Delivery | Material | Description | Item | Plant (DC) | ShPt | SLoc | Name of the Shipping Point | Location of the Shipping Point | Plant (FL) | Ship-to-party | Name of the Ship-to-party | Location of the Ship-to-party | Shpg. Cond. | DHL Pricing Zone | Total Weight | WUn | Air Freight (S3) Cost [XDR] | Sea Freight (S9) Cost [XDR] | Express (S1) Cost [XDR] | Cost per Shipment "Master" [XDR] | Cost per Shipment w/ Sensitivity Factor [XDR] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weekly Consolidation | SBU_FREIGHT | GSS FREIGHT COSTS | 20 | KNES | SGS1 | SG00 | ADC | Singapore | 203 | KEP | Australia Frontline | Matraville | S9 | Zone 1 | 1 626,91 | KG | | 437,13 | | 437,13 | 437,13 |
| Daily Consolidation | SBU_FREIGHT | GSS FREIGHT COSTS | 20 | KNES | SGS1 | SG00 | ADC | Singapore | 203 | KEP | Australia Frontline | Matraville | S1 | Zone 1 | 84,60 | KG | | | 216,00 | 216,00 | 216,00 |

| Weekly Consolidations | | | | | Daily Consolidations | | | | | Annual Delivery Transportations | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Weekly Consolidated Shipment [kg] | Cost per Shipment [XDR] | Annual Shipments [pcs] | Sum of Weekly Consolidation Consortiums [kg] | Total Cost of Weekly Consolidation Consortiums [XDR] | Daily Consolidated Shipment [kg] | Cost per Shipment [XDR] | Annual Shipments [pcs] | Sum of Daily Consolidation Consortiums [kg] | Total Cost of Daily Consolidation Consortiums [XDR] | Total Weight of Annual Delivery Transportations [kg] | Total Sum of Annual Shipments [pcs] | Total Cost of Annual Delivery Transportations [XDR] |
| 1 626,91 | 437,13 | 52 | 84 599,36 | 22 730,71 | 84,60 | 216,00 | 250 | 21 149,84 | 53 999,60 | 105 749,20 | 302 | 76 730,31 |

**Figure 22. View of the modeling tool's inventory and transportation modules and related calculations**

*6.* After the what-if scenarios had been modeled and all the needed scenario calculations made, then the *sixth step of the process* was the scenario comparison and analysis phase. During this step, the scenarios were compared against each other and analyzed in terms of the main network design decision variables raised from the literature review:

*i.* *Service level provided by logistics* → Service ability analysis

*ii.* *Tied-up capital and related efficiency* → Capital efficiency analysis

*iii.* *Total annual logistics costs* → Cost-effectiveness analysis

During this step, also the results of the performed sensitivity analyses were covered with a focus on these decision variables and how they change when the key inputs were changed (*demand* - *transportation costs* - *warehousing costs*). The purpose of all this was to find out what are the relative "balances of power" between the different scenarios in light of the numbers and to create a stance of what could be the most prolific yet robust alternative both now and in the future.

*7.* When this comparative scenario analysis was completed, then *the seventh step of the research process* was to sum up the results and evaluate them against the company's logistics strategy, operational environment as well as other practical considerations in order to form a recommendation for the future. The objective of the study was to find the most profitable and operationally efficient way to distribute spare parts in the area for the future. This was fulfilled by introducing a two-step development roadmap to more efficient yet effective spare parts distribution for the future. The evaluation was also visualized using a decision matrix, which and the way it works is presented in APPENDIX 4.

*8.* After the recommendation for the future direction had been reached, then *the second to last or eighth step* was to consider the impacts of this on maintenance service. The aspects that were considered during this more far-reaching analysis were possible effects of the development path on daily maintenance work along with influence on the end customer satisfaction. This section was included in the study in order to highlight the customer service aspect, which along with both financial performance and competitive advantage should be among the higher-level interests of every logistics related development work.

9. *Finally*, as the study had virtually been concluded the last step was to highlight the constraints encountered during the study and to analyze why and how these had affected the study. This is valuable information so that the results of the study can be evaluated and interpreted in the right way. During this step, some additional research topics were also considered through which the study could be complemented in the future, if necessary.

## 6.2 Assumptions made during the distribution network study

During the distribution network study, a set of assumptions and generalizations had to be made to simplify both operations and issues as well as keep the scope of the study under control. In order the audience to be aware of these choices, the most meaningful assumptions have been compiled in Table 11 below. These have likewise been grouped in classifying categories based on their factual connections.

**Table 11. Collection of assumptions made during the distribution network study**

<table>
<tr><th>Group</th><th>Assumption(s) made</th></tr>
<tr><td>Sourcing and supply</td><td><ul><li>It is assumed that material sources can be generalized and according to this SKUs categorized into three basic groups of origin based on their supplying as follows:<ul><li>EDC materials, that are sourced and supplied from Europe</li><li>CDC materials, that are sourced and supplied from China</li><li>Local materials, that are sourced and supplied from local external vendors</li></ul></li><li>It is assumed that spare parts are stored in the supply sites (EDC and CDC) and that they will be readily available whenever needed (within the limits of the replenishment lead times)</li></ul></td></tr>
<tr><td>Material flows</td><td><ul><li>Materials are assumed to flow as in a complete world without any breaks or other problems</li><li>Material is assumed to not either disappear or increase in the distribution network as it makes its way from the supply-side to the demand-side<ul><li>Hence for instance, in warehouses total annual outbound volumes will be equal to total annual inbound volumes</li></ul></li></ul></td></tr>
<tr><td>Warehousing</td><td><ul><li>It is assumed that APA area frontlines' local storages (SLocs) can be aggregated and handled as a whole to achieve the needed higher-level (Plant) point of view in both warehousing and distribution<ul><li>These aggregated stocks are supposed to be located in the existing "Plant warehouses", which nowadays already serve as country level waypoints in the distribution chain</li><li>In terms of network modeling, these aggregated stocks are treated as NDCs that in a centralized manner hold stock to meet the needs of the country in question and being able to deliver parts to every corner of the country on the same day via express</li></ul></li></ul></td></tr>
</table>

| | |
|---|---|
| | • In warehousing planning, it is assumed that:<br>○ If a globally sourced item in frontline’s NDC was not distributed via the core distribution chain during the fiscal year 2017 (not a so-called VL06O item), then it can be considered as a “slow-moving global item” and a standard sized stock (against 2-year demand) be set<br>○ If an item in frontline’s NDC has not had any demand during the demand period under review (2016-2017), then it can be considered as “deadstock” and the possibly existing stock be left in the warehouse using the following bylaws:<br>▪ No longer planning; let the residual stock run out by itself<br>▪ The item has been recorded as an operating loss and hence a lower holding cost (7%) will be incurring<br>○ Inventories in the distribution area can be replenished at SKU level at most 52 times a year<br>▪ In this way, by controlling the replenishment cycles transportation planning can be simplified<br>○ IN 282 frontline’s NDC is a “special case” in the warehouse planning and needs special treatment in terms of its Local materials, which share of the entire material pool is ~94% with substantial annual warehouse outbounds<br>▪ In planning, Local materials’ SLc [%] should be left unchanged to 99%, while the globally distributed active items (VL06O) can follow the materials management settings normally |
| *Transportations* | • 3PLs are assumed to have the needed skills and readiness to consolidate transportation needs, and that they will use this to carry out both line-haul and delivery transportations |
| *Demand* | • It is assumed that the annual demand in each market area and as a whole can be derived from past warehouse outbounds<br>○ Annual demand used in the study has been calculated as an aggregated smoothed average from 2016-2017 outbounds (to obtain a sufficient sample of demand)<br>• The form and the type of demand is assumed to remain the same in the future<br>○ In the sensitivity analysis, demand growth can hence be taken into account in warehouse planning by bonding the needed demand parameters to the coefficient of variation (CV), which will remain constant under this assumption<br>• It is assumed that all items in stock are somewhat equally necessary for end customers, and hence a stockout will have in every situation same kind of consequences<br>○ This assumption had to be made because despite several attempts, reliable information on item level criticality was not available during the study |
| *Costs and prices* | • It is assumed that the cost accounting criteria for logistics costs would remain as things currently stand as the time passes, and that the costs of the future can be estimated with sufficient accuracy on the basis of current cost data<br>• It is assumed that the product prices and thus their values would remain more or less the same as the time passes, and that the current values will with sufficient accuracy represent the foreseeable future |
| *Distribution network* | • The warehouse structure of the distribution network is supposed to be geographically fixed to the current state, but changes can be freely made to material flows, intermediate structures and weighting of storages among other things in order to explore what would be the most appropriate global distribution network structure for the future |

## 6.3 Data protection

In order to protect the sensitive business information that is handled in the study, the data coming to this report is encrypted by means of different coefficients. Also, some names and terms have been changed to protect the case company. In addition to these, the currencies to be used have likewise been changed to correspond the special drawing right [XDR]. In this way, a secure entity has been successfully created that can be published safely.

As for the aforesaid special drawing right or SDR (currency code XDR), it is so-called "world money" i.e. a supplementary foreign-exchange reserve asset defined and maintained by the International Monetary Fund (IMF). The value of the SDR is based on a basket of five major currencies (*the U.S. dollar*, *the euro*, *the Chinese renminbi*, *the Japanese yen* and *the British pound sterling*), which is reviewed every five years. Technically, SDRs are, though, neither a currency nor a claim on the IMF. Rather, they are a potential claim on the freely usable currencies of IMF members. SDRs are used to take loans or make repayments made by the IMF. During times of economic turmoil, SDRs are also exchanged between the members' central banks to help assure currency reserves. Because of its guaranteed position and universality, some international organizations such as Universal Postal Union and Asian Development Bank use the XDR (instead of the U.S dollar) as a unit of account to cope with exchange rate volatility. Also, several 3PLs like DHL and UPS rely on this when stating their general terms and conditions. (Daily Reckoning 2016; IMF 2018; Investopedia 2018)

# 7 CURRENT STATE ANALYSIS IN THE CASE COMPANY

The presented literature review was conducted to gather an all-encompassing theory base on the characteristics and guidelines that influence distribution network design and operations planning in global spare parts business. In this latter phase of the thesis, this theory set will be applied to the case company and its distribution network in the APA service area to analyze the state of the prevalent operations as well as to produce profound recommendations for the future.

This chapter (Chapter 7) focuses on analyzing the current state in the case company. The chapter starts with a concise case company presentation, through which the subject as well as the context of the network design study are briefly opened. This is followed by an in-depth current state analysis, where the prevalent course of action in APA area distribution is first delineated and then dismantled and analyzed piece by piece. As a result of this analysis a set of observations and development ideas are obtained, which along with the presented literature findings are then used as inputs to the what-if scenario analysis phase. This part of the network design study will be discussed more specifically later (Chapters 8 and 9).

## 7.1 Company presentation: KONE Industrial Oy, Global Spares Supply

The case study was conducted for KONE Industrial Oy, Global Spares Supply (or briefer KONE GSS) which is a spare parts department of the multinational industrial equipment manufacturer and service provider KONE Corporation. KONE was founded in Finland in 1910 and is a global leader in the elevator and escalator industry. Besides these core products, KONE's portfolio also features other products like automatic doors, autowalks, access, monitoring and destination control systems. Hence, KONE offers a wide variety of innovative and sustainable new equipment solutions as seen in Figure 23 below. In addition to this, KONE also provides modernization solutions for aging equipment and ensures both safety and availability in operation in the form of maintenance services. KONE's net sales were 8 950 MEUR in 2017 and it employed over 55 000 employees worldwide. (KONE 2018b; KONE 2018c)

(KONE 2018d)

**Figure 23. Collection of KONE products (elevator, escalator, automatic door and access solution)**

In general, KONE’s business lines divide into New Equipment Business (NEB) and Service Equipment Business (SEB). Maintenance, which represents the supply of services, is likewise a significant part of KONE’s business. In 2017, this in fact generated almost one third of the overall net sales (~32%) and it has become one of the most important sources of revenue, profit and growth. Besides this, maintenance is also seen strategically meaningful in the company to enhance its overall service standard and branding. KONE’s maintenance business provides a variety of maintenance and monitoring solutions including rapid response, smart preventive solutions and expert advice, which together maximize safety and reliability while minimizing downtime and costs. (KONE 2018b; KONE 2018c)

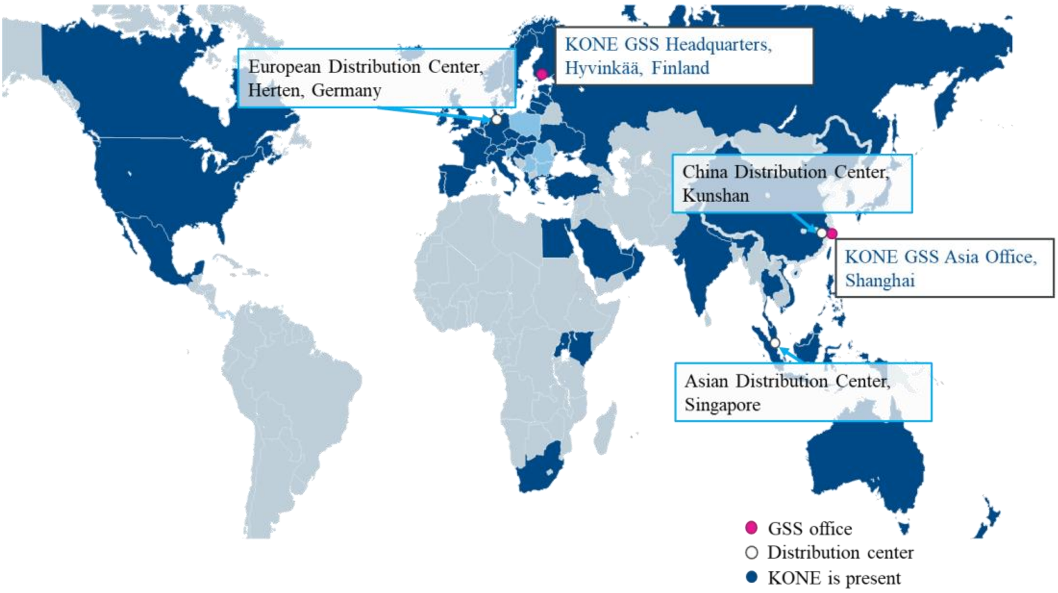
At the heart of the maintenance business is spare part operations, of which KONE GSS accounts for. KONE GSS is an internal centralized supply unit that provides spare part solutions for both internal and external customers. KONE GSS’ service offering constructs of *materials* (spare parts, tools, clothes and PPE), *optimized supply chain solutions* with online visibility and ordering tools, and *maintenance field support* (comprehensive knowledge of spares, maintenance and installations). Following Figure 24 illustrates this trinity with which KONE GSS aims to be the preferred maintenance partner in the industry. (KONE2018c)



(KONE 2018d)

**Figure 24. KONE GSS' service offering**

Such as is the case for the KONE Corporation as a whole, KONE GSS' service area also covers almost every continent including Europe, Africa, Asia and Australia/Oceania. The main market areas are EMEA which accounts for ~85% of total annual revenue and APA with ~15% share (situation in 2017). Like in every industry, it is however expected that the future growth will progressively come from emerging markets. Figure 25 below elucidates KONE GSS' presence worldwide. (KONE 2018b; KONE 2018c)




(KONE 2018c)

**Figure 25. KONE GSS worldwide**

To describe a company and its inner meaning more precisely a set of vision, mission and strategy is often introduced. In this case, this is particularly important because logistics network design goes well over strategic issues. For the case company KONE GSS, these are stated as follows:

- Vision – KONE GSS' vision is "*Right part at the right time to the right place cost-effectively and at the optimized inventory costs*". (KONE 2018c)
- Mission – KONE GSS' mission is "*We enable maintenance to win with customers through effective, responsive and reliable supply chain solutions*". (KONE 2018c)
- Strategy – As a part of KONE Corporation, KONE GSS shares the same strategy with the group which is stated as "*Winning with Customers*". Winning with Customers focuses on putting the needs of customers and end users at the center of all operation and development at KONE. To bring the strategy to life, the group has harnessed the four *"Ways to Win"* with their customers including:
    - *customer-centric solutions and services*
    - *true service mindset*
    - *collaborative innovation and new competencies*
    - *fast and smart execution*

  These form the so-called KONE way of doing things and are the practical means to make progress in daily work. (KONE 2018a; KONE 2018b)

## 7.2 Structural presentation of the Baseline (2017)

As outlined, the case study was conducted for the spare parts department of a multinational industrial equipment manufacturer and service provider. The following sections concentrate on describing, modeling and analyzing the current state operations and performance of the ascending APA area distribution, which is at the focal point of network design and development activities in this study. As has been stated, the distribution operations and network structure will be covered in the higher-level (*global-regional-national*) without getting too in touched with the local distribution and its various sides. The time span used in the current state analysis is the fiscal year 2017.

### 7.2.1 Modeling of the current state

The case company's distribution system in the APA service area is currently a multi-echelon like with central logistics, and in terms of network design is constructed from two main global distribution centers (GDCs), a regional distribution center (RDC) and a cluster of frontlines (FLs) and their nationally located distribution centers (NDCs) confronting the country specific parts demand. The global distribution chain and materials within it flow hence from these supplying distribution centers (*EDC* and *CDC*) to the frontlines (*AU*, *NZ*, *ID*, *PH*, *MY*, *SG*, *TH*, *IN*, *VN*, *TW* and *HK*) via a regional distribution center (*ADC*) that acts as a consolidating central stock for the area. To move material within the network two types of transportations are needed: *line-hauling between DC-to-DC* and *delivering between DC-to-FL*. In addition to this, direct delivering from global distribution centers also takes place in the current state. To cover their annual material needs frontlines likewise source to varying degrees from local external vendors. Figure 26 below illustrates this current form of distribution in the APA service area.

As for materials, APA service area's material scope is consisted of around 19 200 stock keeping units. From this entity ~30% come from Europe (EDC origin), ~20% from China (CDC origin) and the rest (~50%) is sourced and supplied locally from various external vendors (Local origin). Hence, somewhat half of the needed material is supplied abroad and flows along the aforesaid global distribution chain. In the current state, a trace of Local items centrally sourced by the regional distribution center (ADC) also joins this flow at the Asia end. These globally distributed active items are addressed in the study using the abbreviation "VL06O".

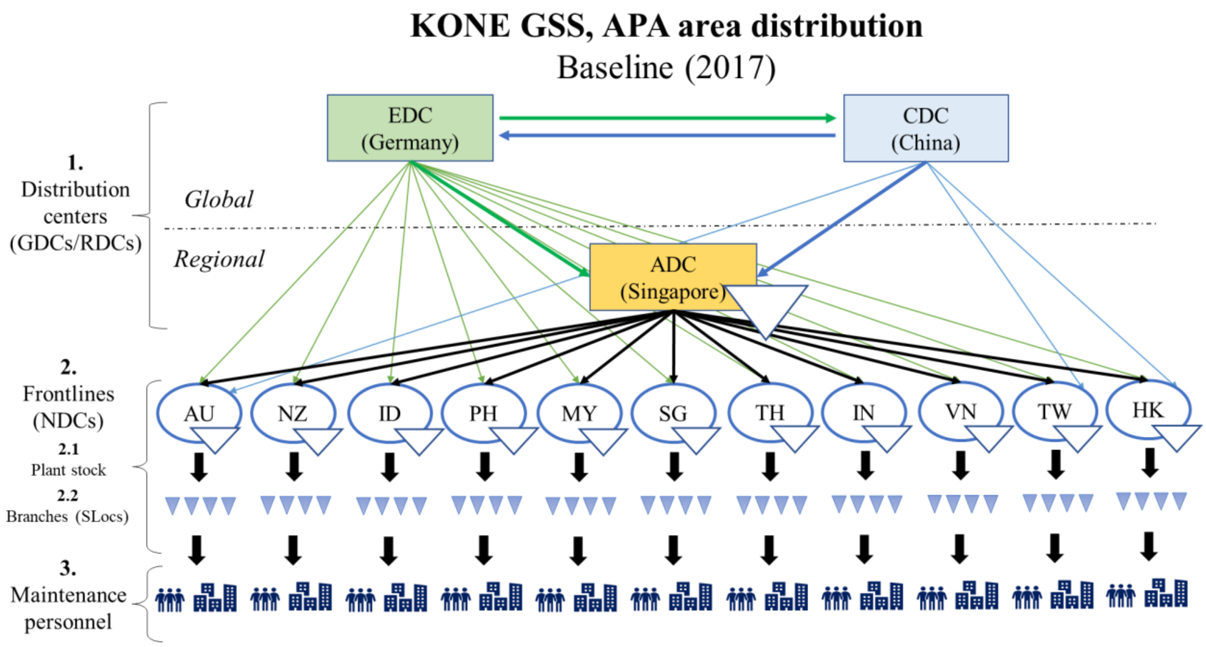



**Figure 26. Illustration of the Baseline (2017) in KONE GSS' APA area distribution**

As was stated, the company's two global distribution centers act as supply sites for the area in question. The distribution centers are located in *Herten, Germany* and *Kunshan, China* from which originates their official abbreviations (EDC = European Distribution Center and CDC = China Distribution Center) as well. The distribution centers are being replenished by hundreds of suppliers each and they are assumed to hold stock in the way that the items originating from these supply sites will be readily available whenever needed.

The regional distribution center serving as a central stock function in the network is in turn located in Singapore, where just about lies the alleged demand center of gravity of the service area. Like in above, the official abbreviation of this regional site originates from geography and is ADC (= Asian Distribution Center). In the current structure, ADC acts as consolidating intermediate storage, which is holding items coming from both EDC and CDC and distributes these to the frontlines according to replenishment needs. Hence, ADC confronts demand for the APA area regarding the globally distributed items and is assumed to be able to supply goods in the time specified by the replenishment lead times (see APPENDIX 3 for more information). As was noted, ADC also sources centrally some items from local external vendors, but this volume is pretty small in comparison to the "main sourcing flows". As for the role of ADC, it is in place to support the replenishment of the frontlines' NDCs and to serve as a safety reserve for the APA area against possible supply and/or demand issues. It also acts as a sourcing site that sources a compact set of items from local vendors and supplies these not only to the APA frontlines but also to China and Europe. The following Table 12 encapsulates the key figures of ADC central stock function grouped into three data groups, which are *stocking data*, *inventory operative data* and *operating cost data*.

**Table 12. Key figures of ADC (Singapore) central stock function in the Baseline (2017)**

| Data Group | Key Figures | ADC (Singapore) |
|---|---|---|
| Stocking Data | Onhand [pcs] | 386 188 |
| | Onhand [XDR] | **2 560 953,81** |
| | Total Annual Fcast [pcs] | 461 715 |
| | Total Annual Fcast [XDR] | 5 640 919,37 |
| | Orders During Year [orders] | 61 915 |
| Inventory Operative Data | Weighted AVE SLc [%] | **83,00 %** |
| | AVE Inventory Turnover | **1,60** |
| Operating Cost Data | Total Operating Costs [XDR] | **1 230 789,08** |
| | Holding Costs [XDR] | 1 134 486,49 |
| | Ordering Costs [XDR] | 96 302,59 |
| | Total Duty Payable [XDR] | - |

The final part of this global distribution chain is the frontlines and their NDCs, which act as central warehouses for the destination countries and from a distribution point of view thus confront the demand of the country centrally. Frontlines' NDCs store both globally distributed items and local materials that they source from external vendors on their own. As the need emerges, NDCs further distributes spares to the end-use destinations that can be either a branch's local storage from which local staff will receive the spare parts or the worksite directly. In this regard, it is assumed that these NDCs are able to deliver parts to every corner of the country on the same day via express parcel. In reality, the local distribution chain and both operations and network behind this are, though, more multifaceted than the aforesaid, but this is already beyond the scope of the study and hence ruled out. The following Table 13 summarizes the key figures of APA area frontlines' NDCs grouped into four data groups, which are *stocking data*, *inventory operative data*, *operating cost data* and *inventory inefficiency data*.

**Table 13. Key figures of APA area frontlines' NDCs in the Baseline (2017)**

| Data Group | Key Figures | APA area Frontlines |
|---|---|---|
| Stocking Data | Onhand [pcs] | 1 148 310 |
| | Onhand [XDR] | **7 030 384,54** |
| | Total Annual Fcast [pcs] | 1 462 361 |
| | Total Annual Fcast [XDR] | 12 676 515,79 |
| | Orders During Year [orders] | 31 051 |
| Inventory Operative Data | Weighted AVE SLc [%] | **70,11 %** |
| | AVE Inventory Turnover | **0,30** |
| Operating Cost Data | Total Operating Costs [XDR] | **1 287 937,05** |
| | Holding Costs [XDR] | 1 239 640,32 |
| | Ordering Costs [XDR] | 48 296,73 |
| Inventory Inefficiency Data | Theoretical Stockouts [occasions] | 47 405 |
| | Total Annual Stockout Costs [XDR] | **1 866 385,22** |

As was stated, to keep wheels rolling in the network two types of transportations, *line-hauling* and *delivering*, are needed. In the current structure, line-haul transportation occurs between EDC-ADC and CDC-ADC, which are the so-called "established transportation lines". In addition to these, there is also generic material movement in both ways between EDC and CDC, but this is not that relevant considering the study scope. Consequently, delivery transportation occurs in the network mainly between ADC and the frontlines' NDCs, which is the main delivering entity i.e. "ADC Centralized Supply". There are also quite significant direct delivering especially from EDC (EDC Direct Supply) but also from CDC (CDC Direct Supply) in place. Table 14 below encapsulates the key figures of these transportation entities in terms of transportation volumes, times and costs.

**Table 14. Transportation key figures of APA area distribution in the Baseline (2017)**

| | | Total Weight [kg] | Number of Shipments [pcs] | Total Transportation Costs [XDR] | |
|---|---|---|---|---|---|
| Delivery Transportations | ADC Centralized Supply | 318 640,35 | 16 155 | 710 568,90 | |
| | EDC Direct Supply | 127 173,35 | 6 463 | 489 539,62 | |
| | CDC Direct Supply | 2 580,16 | 11 | 197,04 | |
| | **Total (Intermediate Result)** | **448 393,85** | **22 629** | **1 200 305,56** | (A) |
| Line-haul Transportations | EDC-ADC | 187 947,77 | 7 293 | 151 724,11 | |
| | CDC-ADC | 139 345,02 | 3 753 | 41 457,37 | |
| | **Total (Intermediate Result)** | **327 292,78** | **11 046** | **193 181,48** | (B) |
| | **Total** | **775 686,63** | **33 675** | **1 393 487,04** | (A+B) |

When it comes to modal choices, both transportation types use to varying degrees all the following transportation modes: *sea freight*, *air freight* and *express parcel*. The extent of using each mode will understandably vary between these, which will be returned later on. In general, line-hauling strives though to be as cost-effective as possible by moving large shipments in bulk while delivering tends to be more responsive and effective yet not forgetting costs incurring.

As for the implementation and daily operation of the distribution network, the case company relies here heavily on 3PLs' services. The company has outsourced its warehouse operations (GDCs, RDC and NDCs) and transportations (line-hauling and delivering) to external service providers but plans and manages both internally. In terms of transportation, the company has contracts with all major freight companies operating in the region but has inevitably focused warehousing for certain well-chosen operators. All in all, the 3PLs used are all well-known global players with high reliability and service performance. As a wrap up considering the current state of distribution in the APA area, following Table 15 summarizes the key figures of this "Baseline (2017)" from a senior management point of view.

**Table 15. Summarization of distribution management figures in the Baseline (2017)**

| | *Management Figures - APA area Distribution* | |
|---|---|---|
| **Scenario** | **Baseline (2017)** | |
| Tied-up Capital [XDR] | 9 591 338,35 | |
| Total Annual Logistics Costs [XDR] | 3 912 213,18 | |
| Annual Inefficiency Costs [XDR] | 1 866 385,22 | |
| Service Levels (SLc) [%] | **APA Frontlines** | **ADC** |
| | 70,11 % | 83,00 % |
| Inventory Turnovers | **APA Frontlines** | **ADC** |
| | 0,30 | 1,60 |

### 7.2.2 Detailed breakdown of the current state

The previous section acted as a top level or management introduction to the case company's distribution system in the APA area. In the following sections major parts of this network are dismantled and covered in more detailed manner to provide an inclusive view of the distribution operations, related characteristics and possible deficiencies which undermine both the efficiency and effectiveness of the system. The focus is to bring up general observations and findings that might be useful in terms of distribution network design and operations development. In the entity, the sub areas of the network will be covered in the following order: *ADC (Singapore), APA area frontlines' NDCs*, *delivery transportations* and *line-haul transportations*.

**ADC (Singapore)**

As was noted above, in the current state ADC (Singapore) stores globally distributed items (EDC and CDC origin) while acting simultaneously as a central sourcing channel for a small number of localized spare parts. Thus, ADC's mission is to bring together and connect the supply flow from the world (the supply-side) and the spare part need of the distribution area (the demand-side). Mostly, ADC succeeds in its task, but there is some notable inefficiency both in the operation of the central warehouse and in the network, which consequently are reflected on the entire business. This inefficiency has been one of the reasons for studying the distribution network and the need for this Singapore DC (ADC) in the future.

From the Table 12 above, it can be seen that in the light of higher-level figures, ADC is doing relatively well considering the characteristics of spare parts and the requirements of the business. Regarding the designated role of ADC, however, it seems that this tends to accumulate too much stock, which in the long run ties up heavily capital and hence the circulation of material suffers. The warehouse also appears to suffer quite heavily from "deadstock" which is a kind of plague in spare parts industry. This means that there are items in the stock that does not have any demand. The aforesaid issues are also manifested in terms of rising operating costs, which is further emphasized in the occidental Singapore where price levels tend to be much higher than the average in this APA region.

However, Singapore's central location in terms of the APA service area (the so-called demand center of gravity) supports central stockholding in the country. Another factor advocating Singapore is the country's political stability along with its favorable trade regulations which facilitate the cross-border movement of goods. In the country, ADC operates under the Major Exporter Scheme (MES) where the 3PL act as an agent, that is managing the goods, their movement and relating warehousing. In this way, the global distribution is not subject to unnecessary bureaucracy or additional taxes and customs duties (GST) that would hamper the operation. In more regulated countries, the former would be rather a rule than an exception. (IRAS 2018; Singapore Customs 2018)

### APA area frontlines' NDCs

APA area frontlines, which are considered in this network study as internal customers, consist of 11 countries that form the distribution area to be served. Because the area itself is quite large, the frontlines spread in a fairly wide geographic area. This in turn creates additional challenges for distribution operation and network design. The following Table 16 compiles the APA area frontlines and their identification details.

**Table 16. Compilation of KONE GSS' APA area frontlines and their identification details**

| | |
|---|---|
| *1. AU 203 = Australia FL, Matraville* | *6. ID 244 = Indonesia FL, Jakarta Pusat* |
| *2. NZ 202 = New Zealand FL, Freemans Bay* | *7. TW 246 = Taiwan FL, Taipei* |
| *3. TH 230 = Thailand FL, Bangkok* | *8. VN 252 = Vietnam FL, Ho Chi Minh City* |
| *4. MY 238 = Malesia FL, Petaling Jaya* | *9. IN 282 = India FL, Chennai* |
| *5. PH 239 = Philippines FL, Makati City* | *10. HK HKG1 = Hong Kong FL, Hong Kong* |
| *11. SG SIN = Singapore FL, Singapore* | |

The scope of the study was limited to this higher-level network structure, so the most interesting aspect considering the aforesaid frontlines are their NDCs, that act as central warehouses for the destination countries and confront their demand centrally. In order to interpret the status quo, a quite vast set of data was collected and analyzed. In the following two-piece Table 17 is gathered the most meaningful figures from a management point of view, through which the current state will be covered by raising observations from the table and its contents. To supplement this, also some additional information will be provided.

**Table 17. Dismantling of APA area frontlines' NDCs in the Baseline (2017)**

| | | | Stocking Data | | | | | | Distributed Items Data | |
|---|---|---|---|---|---|---|---|---|---|---|
| FL | Plant | Main Serving DC | Items in Stock | Onhand [pcs] | Onhand [XDR] | Total Annual Fcast [pcs] | Total Annual Fcast [XDR] | Orders During Year [orders] | Globally Distributed Active Items (VL06O) | |
| **AU** | 203 | ADC | **2 521** | 131 500 | **1 100 914,15** | 146 574 | **3 129 500,47** | 5 511 | 1 074 | 43 % |
| **NZ** | 202 | ADC | **233** | 5 464 | **76 520,82** | 1 963 | **36 558,66** | 189 | 110 | 47 % |
| **TH** | 230 | ADC | **2 642** | 44 435 | **452 111,53** | 74 391 | **731 836,15** | 3 884 | 905 | 34 % |
| **MY** | 238 | ADC | **2 143** | 30 601 | **563 098,80** | 55 655 | **950 959,01** | 2 324 | 813 | 38 % |
| **PH** | 239 | ADC | **2 206** | 24 075 | **442 102,26** | 9 135 | **241 001,19** | 1 254 | 1 137 | 52 % |
| **ID** | 244 | ADC | **1 893** | 30 128 | **3 094,51** | 18 831 | **1 827,79** | 1 196 | 803 | 42 % |
| **TW** | 246 | ADC | **1 264** | 19 101 | **5 188,13** | 21 263 | **7 085,32** | 1 298 | 646 | 51 % |
| **VN** | 252 | ADC | **524** | 9 580 | **929,05** | 2 131 | **383,81** | 352 | 400 | 76 % |
| **IN** | 282 | ADC | **9 866** | 751 481 | **3 127 187,33** | 966 658 | **5 026 073,15** | 9 027 | 568 | 6 % |
| **HK** | HKG1 | ADC | **2 663** | 90 436 | **984 206,66** | 134 572 | **1 730 760,42** | 3 250 | 768 | 29 % |
| **SG** | SIN | ADC | **924** | 11 507 | **275 031,29** | 31 188 | **820 529,81** | 2 766 | 498 | 54 % |
| | | **Total** | **26 879** | **1 148 310** | **7 030 384,54** | **1 462 361** | **12 676 515,79** | **31 051** | **7 722** | **43 %** |

| FL | Plant | Main Serving DC | Inventory Operative Data | | | | Operating Cost Data | | | Inventory Inefficiency Data | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | MEDIAN Inventory Turnover (2017) | Items in Stock w/o Demand | Weighted AVE SLc [%] (2017) | Warehouse Outbounds (2017) [occasions] | Ordering Costs [XDR] | Holding Costs [XDR] | Total Operating Costs [XDR] | Theoretical Stockouts (2017) [occasions] | Annual Stockout Costs [XDR] |
| **AU** | 203 | ADC | 0,98 | 42 % | 41,31 % | 25 171 | 8 571,81 | 167 906,50 | **176 478,31** | 14 773 | 581 628,71 |
| **NZ** | 202 | ADC | 0,00 | 60 % | 47,68 % | 302 | 293,97 | 9 385,24 | **9 679,21** | 158 | 6 220,63 |
| **TH** | 230 | ADC | 0,20 | 45 % | 97,63 % | 14 198 | 6 041,17 | 68 106,35 | **74 147,52** | 337 | 13 268,05 |
| **MY** | 238 | ADC | 0,31 | 41 % | 74,81 % | 14 868 | 3 614,75 | 100 076,27 | **103 691,02** | 3 745 | 147 444,63 |
| **PH** | 239 | ADC | 0,04 | 49 % | 96,81 % | 2 480 | 1 950,47 | 74 352,18 | **76 302,65** | 79 | 3 110,31 |
| **ID** | 244 | ADC | 0,00 | 54 % | 7,83 % | 22 235 | 1 860,26 | 511,94 | **2 372,19** | 20 493 | 806 831,18 |
| **TW** | 246 | ADC | 0,37 | 40 % | 92,68 % | 3 266 | 2 018,91 | 888,46 | **2 907,37** | 239 | 9 409,68 |
| **VN** | 252 | ADC | 0,33 | 44 % | 88,61 % | 720 | 547,50 | 147,07 | **694,57** | 82 | 3 228,43 |
| **IN** | 282 | ADC | 0,13 | 43 % | 100,00 % | 169 657 | 14 040,60 | 617 330,04 | **631 370,63** | 7 | 275,60 |
| **HK** | HKG1 | ADC | 0,00 | 61 % | 63,93 % | 11 116 | 5 055,05 | 155 378,27 | **160 433,32** | 4 010 | 157 877,96 |
| **SG** | SIN | ADC | 1,00 | 30 % | 59,93 % | 8 690 | 4 302,24 | 45 558,01 | **49 860,25** | 3 482 | 137 090,04 |
| | | **Total** | **0,30** | **45 %** | **70,11 %** | **272 703** | **48 296,73** | **1 239 640,32** | **1 287 937,05** | **47 405** | **1 866 385,22** |

<u>Observations from the current state:</u>

- The largest volumes of demand and thus stocks within the service area are located in AU, IN and HK. Comparably the smallest ones are in NZ and VN. As can be seen, the need for material in the area is quite two-parted and this gets even more radicalized in the monetary review because of great exchange rate differences (especially in ID, TW and VN). It is, however, expected that in the foreseeable future the demand in these smaller countries will increase considerably, and therefore their interpretation with the same line as the big ones is in place. In the analysis, both stocks and demand were valued using country specific transfer prices. As can be expected the stock volumes and their regional differences are also reflected in the same proportion to the annual operating costs, both holding and ordering.
- As was previously stated, about half of the stocked materials in NDCs come from abroad being these so-called globally distributed active items (VL06O). The percentage, though, varies somewhat between countries. An exception in this is IN, where the amount of VL06O items is minuscule (~6% of all stocked items) due to local production in the country as well as extensive local sourcing. As for the value of these globally distributed items, the average weighted PVD for VL06O titles in the APA area was ~450 XDR/kg (weighted by inventory on hand [pcs]), which indicates that the products are relatively valuable. However, the dispersion in this was very large (*MIN < 1 XDR/kg* and *MAX > 100 000 XDR/kg*), as with spare parts in general, so it is not possible to draw any far-fetched conclusions on this.
- In item level demand data, the demand patterns followed a similarly varied trend and so the annual forecasted demand depended very much on the item in question. In general, all

NDCs within the area seem to have items with high annual demand (as much as 1000 pcs/a) but most of the items fall into the category of more moderate demand (under 50 pcs/a). There are also items that have even less demand than this (no more than 1 pc/a). When it comes to the dispersion of demand, this alike tends to be somewhat evenly uneven. On average, the coefficient of variation of item level demand confronted by NDCs was CV ~2,8, which indicates that the demand is very discontinuous and sporadic. However, there are also items with a more continuous and smoother demand (CV ~0,2), but the prevailing trend in each country is discreteness with extremes as high as CV ~5,0. This coupled with somewhat moderate demand volumes has, as can be expected, a negative effect on inventory turnovers, which often fell well below 1 as can be seen from the table above.

- There seems to be quite a great number of items in NDC stocks with no demand and this so-called “deadstock” further weakens material rotation. Specifically, this is shown in NZ, ID and HK, where "deadstock" items form over half of the stocking pool and hence a great portion of material is just lying in these inventories, which will make the inventory efficiency look extremely bad. In the analysis, the circulation of the inventory entities (NDCs) was illustrated by using median inventory turnover rates, which was chosen as a method because of the high volatility of circulation in the item level due to the aforesaid reasons. In the APA area, the average value of these median turnovers was ~0,30, which is quite moderate, given even the harsh operating conditions of spare parts industry.
- Inventory service levels i.e. the probabilities of getting items directly from facing warehouses also varies considerably in the area. On weighted average, the service level in the area is ~70% with extremes of ~8% in ID and ~100% in IN (weighted by annual sales hits). Given this, the average service level in the area is quite moderate taking into account the requirements of the business and related benchmark figures, which in turn is reflected in the form of great number of stockouts. These correspondingly cause a quite significant amount of “soft” inefficiency costs annually while also undermining the end customer satisfaction.
- In the current state, ordering frequency is likewise quite high which is particularly noticeable on the transportation side covered next but also in warehouses in terms of increasing ordering costs. This is mainly due to the stockouts described above, but there are also problems with inventory planning and materials management.

### APA area delivery transportations

As was underlaid earlier, the APA area delivery transportations are implemented in a two-fold manner, where along with the centralized supplying from ADC there are also in place partial direct supplying from both supply sites (EDC and CDC). This two-fold delivering model is, though, not necessary the most efficient or effective way to meet the delivery transportation need as can be imagined. The following Table 18 summarizes the key delivery transportation figures in the current distribution network by country and delivery line. In order to properly dismantle the current setup, these figures and the resulting entity will be again disentangled through observations like was done above with the APA area frontlines' NDCs

**Table 18. Dismantling of APA area distribution's delivery transportations in the Baseline (2017)**

| | | ADC (Singapore) | | | EDC (Germany) | | | CDC (China) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| FL | Plant | Sum of Total Weight [kg] | Number of Shipments [pcs] | Sum of Transportation Costs [XDR] | Sum of Total Weight [kg] | Number of Shipments [pcs] | Sum of Transportation Costs [XDR] | Sum of Total Weight [kg] | Number of Shipments [pcs] | Sum of Transportation Costs [XDR] |
| **AU** | **203** | 73 972,06 | 6 845 | 261 525,84 | 31 504,08 | 3 166 | 214 925,71 | 273,06 | 5 | 81,78 |
| **NZ** | **202** | 4 467,63 | 556 | 17 514,45 | 8 449,72 | 352 | 18 931,78 | | | |
| **TH** | **230** | 23 884,66 | 676 | 45 493,79 | 9 797,53 | 310 | 27 787,62 | | | |
| **MY** | **238** | 34 018,59 | 1 575 | 60 080,25 | 5 638,20 | 323 | 24 689,31 | | | |
| **PH** | **239** | 17 291,11 | 486 | 54 181,43 | 18 962,62 | 248 | 28 652,49 | | | |
| **ID** | **244** | 13 124,33 | 1 033 | 31 931,81 | 3 035,50 | 242 | 15 977,23 | | | |
| **TW** | **246** | 16 303,07 | 713 | 50 703,29 | 7 383,96 | 225 | 38 416,70 | 186,52 | 3 | 2,81 |
| **VN** | **252** | 3 967,58 | 173 | 26 534,75 | 577,34 | 51 | 3 889,60 | | | |
| **IN** | **282** | 49 623,22 | 1 110 | 29 803,60 | 10 688,93 | 280 | 16 684,11 | | | |
| **HK** | **HKG1** | 52 330,54 | 1 436 | 111 053,50 | 22 111,92 | 633 | 64 465,58 | 2 120,58 | 3 | 112,46 |
| **SG** | **SIN** | 29 657,58 | 1 552 | 21 746,17 | 9 023,55 | 633 | 35 119,49 | | | |
| | **Total** | 318 640,35 | 16 155 | 710 568,90 | 127 173,35 | 6 463 | 489 539,62 | 2 580,16 | 11 | 197,04 |

| Most Used Modes of Transportation (Shpg. Cond.) [according to weight] | | | Most Used Modes of Transportation (Shpg. Cond.) [according to weight] | | | Most Used Modes of Transportation (Shpg. Cond.) [according to weight] | | |
|---|---|---|---|---|---|---|---|---|
| **1st** | **2nd** | **3rd** | **1st** | **2nd** | **3rd** | **1st** | **2nd** | **3rd** |
| S1 | S9 | S3 | S1 | S9 | S3 | S1 | S3 | - |
| 66,93 % | 15,70 % | 15,64 % | 90,06 % | 5,16 % | 4,42 % | 93,41 % | 6,59 % | |

| Delivery Transportation Shipping Conditions (DC-to-FL) | | |
|---|---|---|
| **Shpg. Cond.** | **Legend** | **Additional Information** |
| *S1* | Express Parcel | |
| *S3* | Air Freight | |
| *S9* | Sea Freight | |
| *S0* | Special Delivery | Same day delivery (2 hrs) |
| *S6* | Special Delivery | Next day delivery |

<u>Observations from the current state:</u>

- In the current state, the majority of global distribution delivering takes centrally place from ADC (318 640,35 kg), yet there are also quite significant direct supplying especially from EDC (127 173,35 kg) but also form CDC (2 580,16 kg). When it comes to regional differences, the largest demand areas in the region are AU, IN and HK where expectedly goes the biggest material flows. Correspondingly, the smallest material flows are heading to the more moderate demand areas of NZ and VN. Elsewhere the delivery transportation figures seem to be somewhat even.
- As was previously stated, the ordering frequency in frontlines' NDCs is quite high, which reflects directly on transportation needs as the required number of shipments increases (as can be noted from the table above). This in turn will and also has led to smaller and smaller deliveries, which in the long run is not a very cost-effective way of operating. Stockouts are also a significant problem in some countries, which has further increased the need for pricier one-time express deliveries.
- As for the modal choices or in other words shipping conditions, the majority of the delivery transportations ~74% takes place via express parcel (S1). On the other hand, this is understandable since as the number of annual shipments increase the average weight of a shipment decreases and hence parcel tends to be the only sensible alternative for these smaller shipments. The second most common mode of transportation is sea freight (S9) ~13% before air freight (S3) ~12%. The rest is handled via different special transportation agreements (S0/S6), which account for ~1% of the total annual transported weight.
- The above-mentioned modal choices and their shares, are also directly reflected in the delivery transportation costs that are quite extensive (1 200 305,56 XDR) at annual level, given the fact that in this case we are distributing just to internal customers. In addition to this, there will be a local delivery transportation on the country level until the item gets to the hands of the end user. All in all, by rationalizing the delivery transportations, the company could cut their annual logistics costs significantly while also increasing the overall operational efficiency.

**APA area line-haul transportations**

In addition to delivering the distribution network also requires line-hauling to complete the transportation system. As was previously noted, in the current state the main line-haul transportation lines are EDC-ADC and CDC-ADC. Besides this there was also material exchange between the supply sites, but this is not that relevant in this study. The following Table 19 complies the key line-haul transportation figures which along with the whole system will be disentangled through the observations below.

**Table 19. Dismantling of APA area distribution's line-haul transportations in the Baseline (2017)**

| | EDC (Germany) | | | CDC (China) | | |
|---|---|---|---|---|---|---|
| | Sum of Total Weight [kg] | Number of Shipments [pcs] | Sum of Transportation Costs [XDR] | Sum of Total Weight [kg] | Number of Shipments [pcs] | Sum of Transportation Costs [XDR] |
| **ADC (Singapore)** | 187 947,77 | 7 293 | 151 724,11 | 139 345,02 | 3 753 | 41 457,37 |
| **Total** | 187 947,77 | 7 293 | 151 724,11 | 139 345,02 | 3 753 | 41 457,37 |

| Most Used Modes of Transportation (Shpg. Cond.) [according to weight] | | | Most Used Modes of Transportation (Shpg. Cond.) [according to weight] | | |
|---|---|---|---|---|---|
| **1st** | **2nd** | **3rd** | **1st** | **2nd** | **3rd** |
| S3 | S1 | S7 | S3 | S7 | S1 |
| 73,74 % | 14,23 % | 12,03 % | 84,00 % | 15,27 % | 0,73 % |

| Line-haul Transportation Shipping Conditions (DC-to-DC) | |
|---|---|
| **Shpg. Cond.** | **Legend** |
| *S1* | Express Parcel |
| *S3* | Sea Freight |
| *S7* | Air Freight |

<u>Observations from the current state:</u>

- In APA area distribution, the main line-haul transportation lines are EDC-ADC and CDC-ADC. Of these, a somewhat more dominant one is the material flow coming from Europe (EDC), but the China material flow (CDC) is, though, pretty close to this in terms of transportation volumes. The biggest differences can be found in numbers of shipments and transportation costs. These differences originate from various factors of which the most meaningful ones are materials to be supplied, transportation modal choices and of course distances to be travelled.

- As was stated earlier, of the entire material pool of APA distribution area ~30% comes from Europe (EDC origin) and ~20% from China (CDC origin). When, this is converted to line-hauling needs it somewhat explains the difference in transportation volumes between the lines.
- As for the transportation modes, there is a slight but very fundamental difference between the line-hauling lines. The CDC material flow relies mainly on sea freight (S3) ~84% and air freight (S7) ~15% while the EDC line uses also parcel in addition to these. In the EDC material flow, material moves ~74% via sea freight (S3), ~14% via express parcel (S1) and ~12% via air freight (S7).
- The transportation modal choices are quite relevant in terms of the line-haul transportation costs, which are approximately three times higher in the EDC line (151 724,11 XDR) versus the CDC line (41 457,37 XDR). The difference is mostly explained by extended distances, but in EDC line the use of pricier express parcel also elevates transportation costs to some extent, while at the same increasing the number of shipments and thus decreasing the average shipment weight. This in turn weakens achieving the much-needed economies of scale and scope in a bigger picture and hence generates unnecessary extra costs.
- All in all, the line-haul transportations seem to work pretty well and there are no major shortages. With a little fixing, the setup would though become even more cost-effective.

## 7.3 Problems and development areas of the current state

As have been seen, in the current state there are some fundamental shortages and structural issues that hinder both the achievable service ability and the financial performance as well as undermine the functionality of the distribution network in general. In the following Table 20 have been collated the emerged problems and development areas by each distribution network building block. At the same time, it is briefly described how these weaknesses could be addressed and translated into strengths in the upcoming what-if scenarios. Hence this compilation works both as a summarization and a great linkage for the distribution network design and development.

**Table 20. Most notable issues hindering the current state and how these could be tackled in upcoming what-if scenarios**

| Section | Encountered problems and development areas in the current state | How could these be tackled in upcoming what-if scenarios? |
|---|---|---|
| *Distribution network* | • Inconsistency of both the distribution network and operations within it, and consequent uncertainty about functioning of the current distribution system in general<br>• Dubiety about the role and meaning of ADC (Singapore) in the distribution system, and what would be the most suitable network structure for the future | In distribution network design and modeling by:<br>✓ Cleaning up the current system and remodeling it in the form of a "Baseline (Optimized)" scenario to get clarity about the current state's potential in terms of network design<br>✓ Developing, modeling and analyzing alternative distribution network scenarios to get an idea of how the current network works and what would be the best distribution solution for the future |
| *Warehousing* | • Incoherent inventory management, control and service policies across the APA area depots<br>• Functioning of the warehouse network is both locally and as a whole far from optimal in the area:<br>1. Lots of capital committed to the system<br>o Overlapping and overstocking<br>2. Poor inventory turnovers<br>o High level of "deadstock"<br>3. Oversized warehouse operating costs<br>4. Moderate service ability<br>o Service level range 8%-100%, with a rough average of ~70%<br>5. High annual inefficiency costs<br>o Wrong products in wrong quantities on hand | In warehouse planning and management by:<br>✓ Introducing the same reorder point-based planning and inventory control method used in other DCs (EDC, CDC and ADC) across the APA area frontlines' NDCs<br>✓ Setting up standard inventory management and service policies across the APA area warehouses<br>✓ Cleansing and optimizing higher-level inventories in the APA distribution area<br>o Concerns APA area frontlines' NDCs as well as all possible central stock functions in upcoming scenarios<br>✓ Paying attention to the functionality and service ability of the entire distribution chain<br>o In spare parts industry, distribution service ability consists roughly of three fundamental factors which all must be in place to succeed. These are:<br>A. Location of stockholding (close to consumption)<br>B. Availability (sufficient availability)<br>C. Delivery process (rapid and flexible deliveries) |
| *Transportations* | • Notable number of contradictory direct deliveries from the supply sites<br>o Need for "rush delivering"<br>• Inefficient use of available transportation modes<br>o Overwhelmed exploitation of both express parcel and air freight across the distribution network (mainly in delivering, but also in line-hauling)<br>• Lots of small individual shipments (both in delivering and in line-hauling)<br>• Oversized transportation costs | In transportation planning and management by:<br>✓ Introducing the parallel multimodal utilization of different transportation modes to transportation planning<br>o Shifting in a greater extent to more cost-effective sea freight, while keeping both air and express modes as a deliberated "fast lane" option for important parts and rush deliveries (both in line-haul and delivery transportations)<br>✓ Introducing consolidation to transportation operations in the sense of stabilizing transportation planning as well as capturing to a greater extent the economies of scale<br>o In line-haul transportations shifting to consolidated weekly sea and air shipments according to the "80/20 rule"<br>o In delivery transportations using consolidated weekly sea/air/express shipments (whichever is the most economical in each case) and daily express deliveries according to the same "80/20 rule"<br>*"With a view to the whole, these are important shifts in the quest of cost-effectiveness, because the global distribution network does not directly serve the end users and thus the value of using faster, yet pricier transportation modes is not that evident"* |

# 8 WHAT-IF SCENARIO ANALYSIS IN THE CASE COMPANY

Once the current state of operation within the distribution area has been analyzed and the prevailing shortages in this discovered, the next phase would be to conduct the so-called what-if scenario analysis. Here the idea is to strive to develop as many different scenario alternatives as needed to address the pointed research questions and thus in this way make it possible to reach a suitable study outcome. As the aim of the study was to find out the most profitable and operationally efficient way to distribute spare parts in the area for the future, the first obvious step was to fix the above-mentioned deficiencies in the current system and test how the current network could work if things would be done by the book. After this, the idea was just to start to think different alternative ways to construct the distribution network and its operations using the literature findings as a basis. In this, the existing network structure was taken as a starting point to the what-if scenario development while also keeping clearly in mind the various requirements and characteristics of the business.

As has been hinted, in the case environment there are numerous factors that clearly advocate a multi-echelon like distribution system with central logistics. However, at the same time there are almost as many factors in the light of which a more decentralized option with direct supplying would be a better solution. To get all the facts affecting on network modeling on the table, these were collated alongside in the Table 21 below.

**Table 21. Collation of factors advocating each distribution network archetype in the case environment**

| A) Factors advocating a multi-echelon system with central logistics | B) Factors advocating a direct supply distribution system |
|---|---|
| **A1. Long distances and replenishment lead times within the distribution area**<br>• The distances and hence the lead times from the supply sites to the APA service area are quite long and therefore it is much more secure and cost-effective to organize the replenishment of the frontlines' NDCs using central logistics (concern especially EDC origin items).<br><br>**A2. A large number of frontlines to be served**<br>• The service area in question is rather extensive as it consists of dozen NDCs to be served (in total 11). Given this, it is both more efficient and effective from a management point of view to design and operate the distribution network through centralized waypoint(s). | **B1. High customer service requirements**<br>• In spare parts distribution, customer service requirements are high (high availability, rapid deliveries and small order volumes) and this combined with long lead times and relatively unpredictable demand (CV) forces to hold substantial stocks in NDCs. To offset this, network modeling drives to seek ways to cut costs elsewhere from the network. In the current state, ADC (Singapore) incurs relative large number of annual operating costs, which can be excised by straight forwarding the network structure with a shift to a more decentralized system with direct supplying. |

| A3. Relatively high but variable parts' product value densities (PVD) | B2. Wide and scattered distribution area with a high regional dispersion of demand |
|---|---|
| • Product value densities (PVD) of the parts to be distributed are relative high but variable, in which case it would be wise to try to centralize the priciest and the slowest moving items with low criticality to a regional central stock in the future. This correspondingly advocates an echelon system with central logistics. | • Geographical scatteredness of the distribution area combined with the high regional dispersion of demand tends to advocate more straightforward means. By using direct supplying, material flows within the network could be rationalized while also avoiding unnecessary transportations (concerns especially CDC-ADC line-hauling but also all delivering in the current state). |
| **A4. Risks associated with stockholding** | **B3. Few supply sites and consequent reasonable number of transportation lines** |
| • There are risks of obsolescence and deterioration associated with stockholding, which are further amplified by the fact that the confronted demand is pretty variable and hence unpredictable. By centralizing distribution with a multi-echelon system, stock levels in frontlines' NDCs and as a whole can be lowered which correspondingly mitigates the risks involved. | • Given the fact there are only two supply sites and 11 NDCs to be served, the number of needed transportation lines is quite reasonable. This on the other hand attracts to try out at least some form of direct supplying. The viability of this depends though on shipment volumes, freight rates and lead times among other things. |
| **A5. Highly unbalanced freight rates** | **B4. Introduction of consolidation and consequent increase of average delivery volumes** |
| • Generally, in a global distribution field the transportation modal options tend to be limited and the freight rates between them highly unbalanced. To be able to utilize the more economical sea freight in the network's delivery transportations in a larger scale, distances and hence lead time differences need to be narrowed down by setting up a waypoint closer to the market. This correspondingly advocates an echelon system with central logistics. | • Introduction of consolidation to both transportation planning and materials management increases in the long run average delivery volumes, which correspondingly enables direct supplying. This does not necessarily advocate one archetype over another, but it impugns the need for centralized network structure. |

As can be seen from the table above, in the light of the theory it is difficult to find one obvious structural solution that would produce the best possible result for our case. Therefore, different alternatives had to be modeled and tested to find out the most suitable solution. This was done by using the modeling tool built for the study. The initial scenarios to be tested and analyzed were the above-mentioned extreme alternatives. Along with these, a couple of well-designed hybrid models that would bring together the best characteristics of the extremes were developed. All in all, four scenario alternatives were constructed and modeled, which were:

A) *Baseline (Optimized) - Centralized Distribution via ADC*
B) *Decentralized Model with Direct Supply*
C) *China Centralization Model*
D) *ADC-China Hybrid Model*

Next, each scenario and their specific features will be described and covered from the top management level. In addition to this, also the output data of related models in terms of operational key figures will be presented to give some intuition of the scenarios' performance and their relative "balances of power".

## 8.1 What-if scenario A: Baseline (Optimized)

The first what-if scenario to be reviewed is the so-called “Baseline (Optimized)” which acts as an optimized illustration of the “Baseline (2017)”. The basic idea behind this was to correct all existing gaps and disadvantages hindering the current state while keeping the network structurally unchanged. In addition to this, the main distribution network building blocks (warehouses and transportations) were optimized by redesigning the functions in accordance with the aforesaid principles and procedures. Thus, the “Baseline (Optimized)” reflects what the current state distribution network might in the best case look like if things would be done by the book. This will likewise serve as an excellent benchmark for the other scenarios and their development measures.

As was stated above, in “Baseline (Optimized)” the distribution network is structurally the same as currently and is thus composed of the two supplying GDCs (EDC and CDC), one consolidating RDC (ADC Central Stock) and a group of APA area frontlines’ NDCs which are the endpoints for this higher-level global distribution. What have changed in the network are the flows of material, which have now been rationalized and remodeled. This has been done by optimally circulating all material activity (in large cost-effective batches) from supply sites to the APA area via the consolidating ADC, which then further distributes the materials centrally to the target countries according to needs. Thus, the contradictory direct deliveries from supply sites to NDCs, which in the present state was incurring considerable costs, have now got rid of. At the same time, this setup is remarkably facilitating distribution planning and management in the network by giving clear frames and processes to the operation as a whole. Figure 27 below illustrates this refined “Baseline (Optimized)” version of the current state. Although not depicted in the figure, APA area frontlines are continuing to run their local sourcing in addition to the illustrated global distribution, which has been taken into account in the planning of the NDCs. At the same time all stocks and transportations in the network have been redesigned, which will be further discussed next.

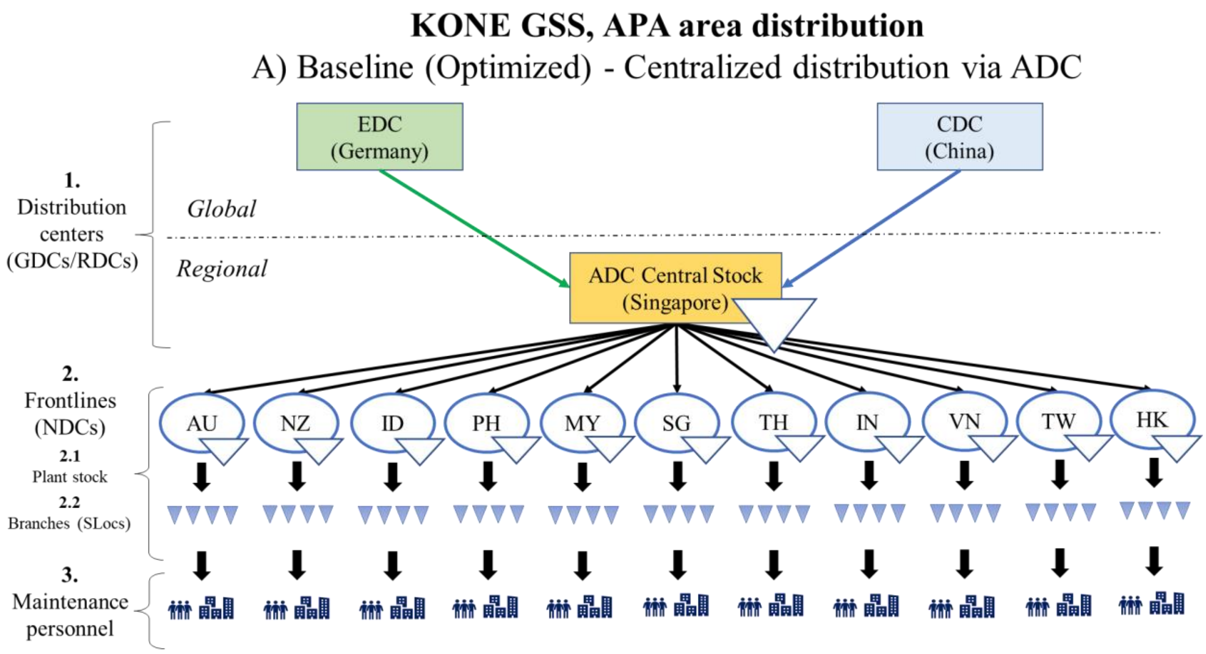



**Figure 27. Illustration of the Baseline (Optimized) scenario in KONE GSS' APA area distribution**

As was mentioned, the RDC of the distribution network is still located in Singapore (ADC Central Stock), where somewhat lies the assumed demand center of gravity in the service area. The operating model of the ADC (the MES scheme) is alike the same as in the current state, but its role has been modified slightly to meet more precisely the actual needs of the APA area distribution, namely cost-effective replenishment and service of the NDCs. This has been accomplished by optimizing ADC's operations and inventory levels from the viewpoint of forward delivering of material, and by excluding all inactive and unnecessary items from the warehouse's material pool (now includes only VL06O items). In inventory planning, ADC's service level was left the same as it was seen that a larger regional central stock will not have any greater added value, given the ADC's assisting role and that its function in the network has already been established from the viewpoint of materials management. For the future, ADC could also serve as a good platform for the centralization of the most expensive and slow-moving titles with a moderate criticality. Because of the lack of reliable information on item level criticality, this had to be, though, excluded from the scenario. The following Table 22 summarizes ADC's key figures in the "Baseline (Optimized)" scenario divided into three data groups, which are *stocking data, inventory operative data* and *operating cost data*.

**Table 22. Key figures of ADC (Singapore) central stock function in the Baseline (Optimized) scenario**

| Data Group | Key Figure | ADC Central Stock (Singapore) |
|---|---|---|
| Stocking Data | Onhand [pcs] | 96 924 |
| | Onhand [XDR] | **1 302 373,55** |
| | Total Annual Fcast [pcs] | 348 344 |
| | Total Annual Fcast [XDR] | 6 072 108,25 |
| | Orders During Year [orders] | 6 222 |
| Inventory Operative Data | Weighted AVE SLc [%] | **83,00 %** |
| | AVE Inventory Turnover | **2,27** |
| Operating Cost Data | Total Operating Costs [XDR] | **590 066,48** |
| | Holding Costs [XDR] | 580 388,79 |
| | Ordering Costs [XDR] | 9 677,70 |
| | Total Duty Payable [XDR] | - |

The APA area frontlines' NDC stocks have likewise been cleansed and optimized in accordance with the generic principles described earlier. The biggest difference in comparison to the current state is the shift of the main focus of the warehouse network closer to consumption, that is to these centralized NDCs where stockholding is creating more value in terms of customer service. This is particularly emphasized in the spare part industry where customer service requirements are very high. The aforesaid has been achieved by relieving intermediate warehousing in the network while raising the NDCs' stockholding and service levels as a whole closer to the industry standards, with the aim of ensuring high availability and rapid local deliveries whenever spare parts are needed. As part of the optimization, replenishment cycles and thus ordering frequencies have also been made more moderate by increasing batch sizes and cycle stocks, which in turn supports efficient transportation. However, as replenishments have now been shifted to a greater extent to more economical yet slower sea freight, which is also more susceptible to delays, small additional safety reserves (sized against 1 MOS) have been set for each NDC to safeguard against potential replenishment or delivery difficulties. To illustrate the effects of these changes, Table 23 below summarizes the key figures of APA area frontlines' NDCs in the "Baseline (Optimized)" scenario grouped into four data groups, which are *stocking data*, *inventory operative data*, *operating cost data* and *inventory inefficiency data*.

**Table 23. Key figures of APA area frontlines' NDCs in the Baseline (Optimized) scenario**

| Data Group | Key Figure | APA area Frontlines |
|---|---|---|
| Stocking Data | Onhand [pcs] | 709 284 |
| | Onhand [XDR] | **6 883 646,23** |
| | Total Annual Fcast [pcs] | 1 462 361 |
| | Total Annual Fcast [XDR] | 12 676 515,79 |
| | Orders During Year [orders] | 20 095 |
| Inventory Operative Data | Weighted AVE SLc [%] | **92,56 %** |
| | AVE Inventory Turnover | **1,10** |
| Operating Cost Data | Total Operating Costs [XDR] | **1 238 613,66** |
| | Holding Costs [XDR] | 1 207 357,89 |
| | Ordering Costs [XDR] | 31 255,76 |
| Inventory Inefficiency Data | Theoretical Stockouts [occasions] | 10 732 |
| | Total Annual Stockout Costs [XDR] | **422 530,24** |

As was previously stated, transportations in the distribution network have taken a significant step forward in comparison to the prevailing situation. This has been made possible through the consolidation of transportations (both line-hauling and delivering), which in its entirety adds more orderliness to both planning and management of material flows. At the same time, warehouse planning has been invested more and given the deserved credit, which have made it possible to utilize more economical yet slower sea freight on a larger scale in the distribution. Similarly, faster modes of transportation (air freight in line-hauling and express parcel in delivering) have been harnessed for the use of emergency supplies and key materials. This layout enables both modal extremes to be used to obtain the underlying benefits in accordance with "the 80/20 rule". As have been delineated, the inventory planning as a whole was, though, based purely on masses according to the principle of prudence, which in this case meant using replenishment lead times of the more dominant form of consolidation. Again, to illustrate the effects of these modifications, following Table 24 encapsulates the transportation key figures in the "Baseline (Optimized)" scenario in terms of transportation volumes, times and costs.

**Table 24. Transportation key figures of APA area distribution in the Baseline (Optimized) scenario**

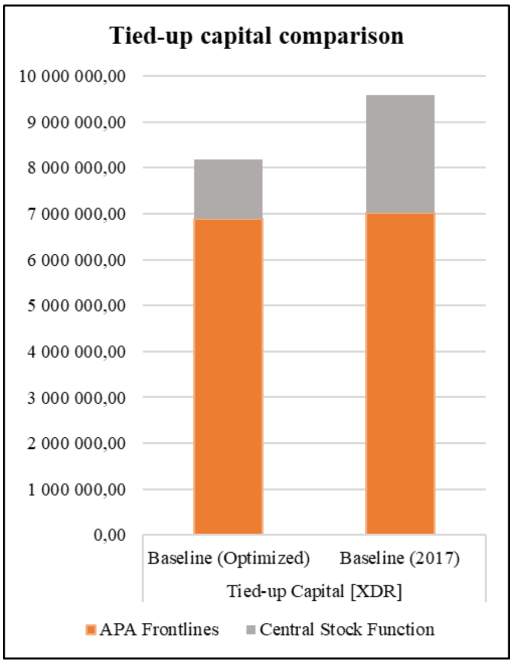
| | | Total Weight [kg] | Number of Shipments [pcs] | Total Transportation Costs [XDR] | |
|---|---|---|---|---|---|
| Delivery Transportations | ADC Centralized Supply | 448 393,85 | 3 322 | 333 833,96 | |
| | **Total (Intermediate Result)** | **448 393,85** | **3 322** | **333 833,96** | (A) |
| Line-haul Transportations | ADC Central Stock; EDC Source | 302 207,53 | 104 | 120 276,25 | |
| | ADC Central Stock; CDC Source | 145 011,66 | 104 | 45 184,82 | |
| | **Total (Intermediate Result)** | **447 219,19** | **208** | **165 461,07** | (B) |
| | **Total** | **895 613,05** | **3 530** | **499 295,03** | (A+B) |

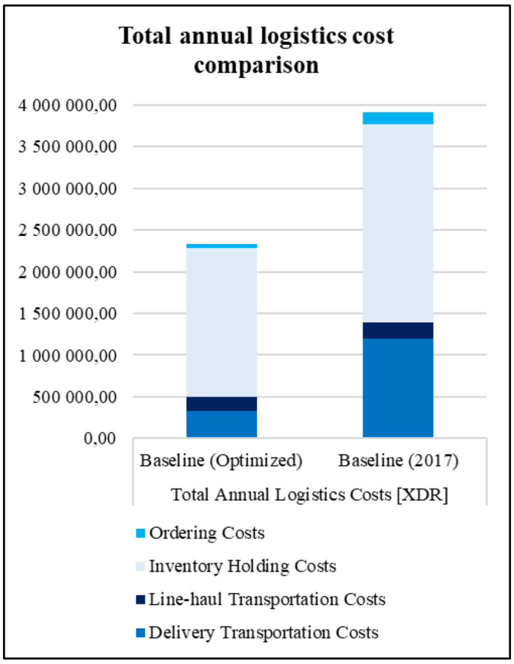
As a wrap up, following Table 25 summarizes the key figures of the scenario from a senior management point of view and presents these in comparison to the "Baseline (2017)".

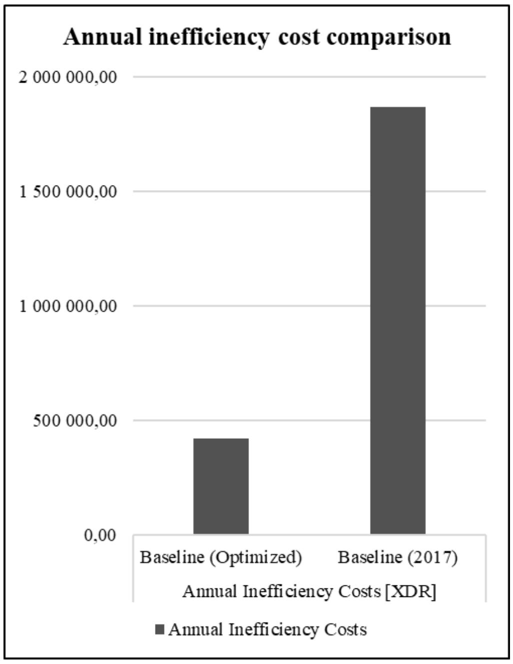
**Table 25. Summarization and comparison of distribution management figures in the Baseline (Optimized) scenario**

*Management Figures - APA area Distribution*

| Scenario | Baseline (Optimized) | | Baseline (2017) | | Change in Comparison to the Baseline (2017) | |
|---|---|---|---|---|---|---|
| Tied-up Capital [XDR] | 8 186 019,77 | | 9 591 338,35 | | -1 405 318,57 | -15 % |
| Total Annual Logistics Costs [XDR] | 2 327 975,17 | | 3 912 213,18 | | -1 584 238,01 | -40 % |
| Annual Inefficiency Costs [XDR] | 422 530,24 | | 1 866 385,22 | | -1 443 854,98 | -77 % |
| (*) Service Levels (SLc) [%] | **APA Frontlines** | **ADC Central Stock** | **APA Frontlines** | **ADC** | **APA Frontlines** | **Central Stock Function** |
| | 92,56 % | 83,00 % | 70,11 % | 83,00 % | 22,45 pp | 0,00 pp |
| Inventory Turnovers | **APA Frontlines** | **ADC Central Stock** | **APA Frontlines** | **ADC** | **APA Frontlines** | **Central Stock Function** |
| | 1,10 | 2,27 | 0,30 | 1,60 | 260 % | 42 % |
| (*) pp stands for percent point | | | | | | |




As can be noted, the development measures have already brought notable improvements over the current state. The most significant change here is the sharp decline in total annual logistics costs (-1 584 238,01 XDR / -40%), which is mainly due to the rationalization of transportations, but warehouse redesigning and optimization have also had its role in the whole. Warehouse optimization has also lowered committed capital in the network (-1 405 318,57 XDR / -15%)

as well as improved inventory turnover ratios (APA Frontlines +260% / Central Stock Function +42%). Likewise, the improved service levels in the APA area frontlines' NDCs (70,11%→92,56%) allow for much better responsiveness, value creation and customer satisfaction, which is reflected not only in the facing fill rates, but also in the probabilities of stockout situations and related annual inefficiency costs (-1 443 854,98 XDR / -77 %).

## 8.2 What-if scenario B: Decentralized Model with Direct Supply

The second what-if scenario to be covered is "Decentralized Model with Direct Supply". The basic idea when starting to build this scenario was the desire to test the other structural extreme i.e. direct supplying to the APA area distribution, and to see what the situation would look like if things were conducted in a completely different way. As was previously explained, this rather radical alternative is supported by the need for keep considerable stocks in the frontlines' NDCs due to the high customer service requirements as well as the geographical scatteredness of the distribution area combined with the high regional dispersion of demand and yet transportation volumes. When these are coupled with the introduction of consolidation to the transportation planning and consequent increase of average delivery volumes, the scenario seems no more so impractical.

As the name already implies, in the "Decentralized Model with Direct Supply" scenario direct delivery lines from the supply sites to all frontlines in the service area were established along which distribution is set to take place. Consequently, the distribution network structure was streamlined and lightened as there are now only the supplying GDCs (EDC and CDC) and the APA area frontlines' NDCs which are again the endpoints for this higher-level global distribution. In the scenario, was also taken into account the recent development activities of the so-called KEA area (AU and NZ) which made it possible to try to integrate distribution operations regionally. With respect to this, an experimental cross-dock platform (KEA Cross-dock) was set up on the side of the AU frontline's NDC to centrally serve replenishment of the KEA area, which in turn enables combining related material flows and thus providing significant economies of scale in this long-distance delivering. Figure 28 below illustrates the described distribution network structure of this "Decentralized Model with Direct Supply scenario" as well as the global material flows within it. Again, although not depicted in the figure APA area frontlines are also running their local sourcing in addition to the illustrated global distribution, which has been considered in the planning of the NDCs. At the same time all stocks and transportations in the network have been redesigned, which will be reviewed next.

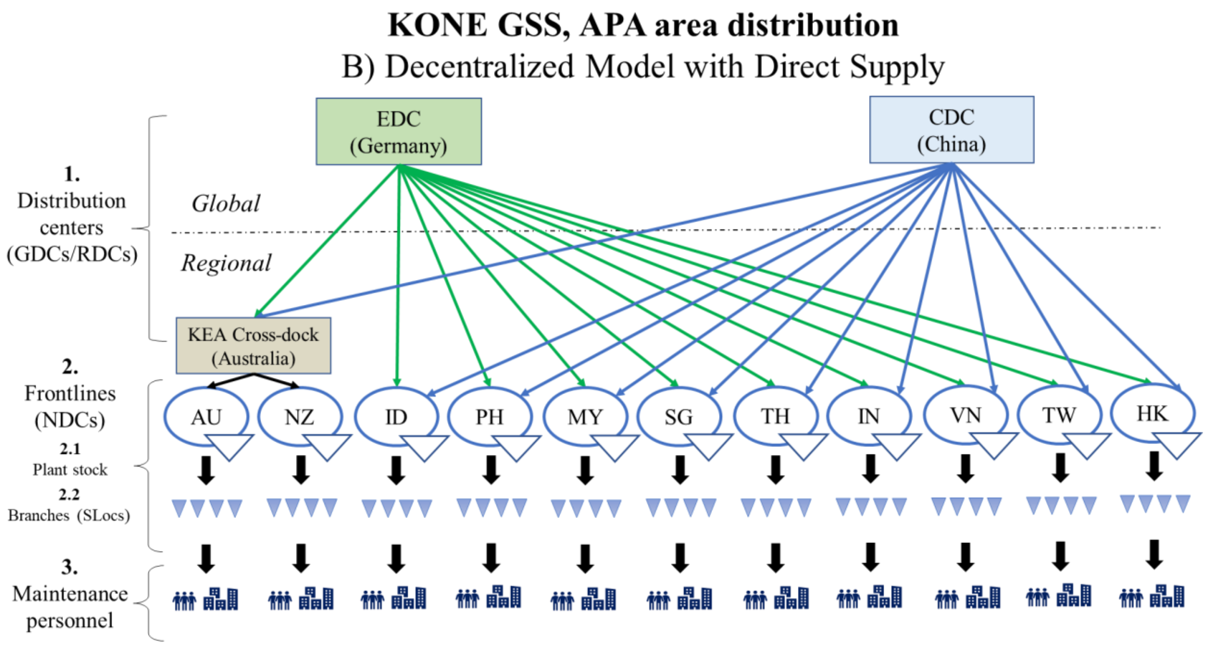



**Figure 28. Illustration of the Decentralized Model with Direct Supply scenario in KONE GSS' APA area distribution**

So, in the scenario a cross-dock was set up for the KEA area to enable cost-effective long-distance delivering while also achieving the significant regional economies of scale. These are obtained by embedding a fairly small target market's (NZ) material flow to the one of a larger market's (AU) in the same tight region in terms of long-haul delivering, which takes place between the supply sites and the KEA Cross-dock. Correspondingly, when the combined shipment has arrived at the KEA area, the cross-dock takes care of unbundling NZ's share from the main stream, which is remaining in the AU, and handles its distribution to the destination country (more specifically to its NDC). In order to carry out this sort of cross-docking arrangement, a regional merger of the order-to-delivery processes along with significant coordination, management and cooperation skills are inevitably needed. Therefore, cross-docking has been harnessed only in the KEA area, where recent development activities have made the arrangement possible by bringing the parties closer together. When it comes to the scalability of cross-docking in the APA area distribution, it was seen that significant benefits were achievable especially with longer journeys but at shorter intervals (intra-APA shipments) this was not currently that prolific due to very unbalanced and inconsistent regional freight rates in the distribution area. Because of this, the arrangement has not been included in other scenarios.

As in the previous scenario, the NDC stocks of the APA area frontlines have been refined and optimized in the scenario in accordance with the previously described principles. Due to the streamlined distribution network, the main focus of stockholding has deliberately been shifted to the immediate proximity of consumption, that is in the NDCs. This has again been reinforced by raising NDCs' service levels as a whole closer to the industry standards, with the aim of ensuring high availability and rapid local deliveries whenever spare parts are needed. At the same time, attention was paid to the functionality and effective replenishment of stocks, taking into account the entire distribution chain. However, as replenishments have now been shifted to a greater extent to more economical yet slower sea freight, which is also more prone to delays, small additional safety reserves have been erected for each NDC to secure against any potential replenishment or delivery difficulties. Since distances and thus replenishment lead times have been increased to target countries due to the direct supplying, it is, though, needed to increase the size of these reserves. As a result of long pondering, for the items to be supplied from EDC the safety reserve was decided to set against 3 MOS and for CDC items against 2 MOS. As can already be divined from the above, this decentralized direct supply system combined with extended distances and delivery times has dramatically increased overall country stocks, which is reflected both in inventory turnover ratios and warehousing costs. Compared with the previous "Baseline (Optimized)" scenario, capital employed to the APA frontlines' NDCs has grown with ~1 490 000 XDR and the annual operating costs with ~460 000 XDR. On the other hand, this is away from the rest of the warehouse network, such as central logistics, which is not needed in this scenario. To wrap up the effects of the aforesaid changes, Table 26 below summarizes the key figures of APA area frontlines' NDCs in the "Decentralized Model with

Direct Supply" scenario grouped into four data groups, which are *stocking data*, *inventory operative data*, *operating cost data* and *inventory inefficiency data*.

**Table 26. Key figures of APA area frontlines' NDCs in the Decentralized Model with Direct Supply scenario**

| Data Group | Key Figure | APA area Frontlines |
|---|---|---|
| Stocking Data | Onhand [pcs] | 763 687 |
| | Onhand [XDR] | **8 368 113,72** |
| | Total Annual Fcast [pcs] | 1 462 361 |
| | Total Annual Fcast [XDR] | 12 676 515,79 |
| | Orders During Year [orders] | 20 311 |
| Inventory Operative Data | Weighted AVE SLc [%] | **92,56 %** |
| | AVE Inventory Turnover | **0,96** |
| Operating Cost Data | Total Operating Costs [XDR] | **1 697 707,74** |
| | Holding Costs [XDR] | 1 666 116,01 |
| | Ordering Costs [XDR] | 31 591,73 |
| Inventory Inefficiency Data | Theoretical Stockouts [occasions] | 10 732 |
| | Total Annual Stockout Costs [XDR] | **422 530,24** |

As has already been mentioned, in this "Decentralized Model with Direct Supply" scenario has been made the pivotal shift from using a two-part transportation chain consisting of delivering and line-hauling to more straightforward direct supplying. Hereby, in terms of transportations the network will be spared from "unnecessary" transfer of material in the distribution area. However, the weaknesses of direct supplying are the prolongation of both distances and lead times, the increase in the required times of transportation and the consequent reduction in the average delivery volumes as well as the need to shift the use of fast transportation modes to even longer journeys to keep the wheels turning. Due to these factors, the transportations costs are increasing and at the same time the role and especially the reliability of transportation will be emphasized in the distribution chain. When it comes to the operational side of transportations, the supplying is planned to follow the same consolidation combined with the parallel multimodal use of transportation modes procedure as before in accordance with the "80/20 rule". This brings the demanded systemicity and manageability to the entire flow of materials while allowing cost-effective implementation. The following Table 27 illustrates the transportation key figures of this "Decentralized Model with Direct Supply" scenario. As shown in the table, in the transportation planning has also included the Local items joining the global distribution flow currently sourced by ADC (i.e. VL06O Local). In the scenario, these are ostensibly delivered from the ruins of ADC to the countries once a week via express parcel.

Although this is not of any practical significance, it was desirable to do so in order to get the transportation needs to match between the modeled scenarios.

**Table 27. Transportation key figures of APA area distribution in the Decentralized Model with Direct Supply scenario**

| | | Total Weight [kg] | Number of Shipments [pcs] | Total Transportation Costs [XDR] |
|---|---|---|---|---|
| Delivery Transportations (Direct) | EDC Direct Supply | 204 865,54 | 2 718 | 290 992,12 |
| | CDC Direct Supply | 123 857,44 | 2 718 | 162 384,45 |
| | [ VL06O Local Supply ] | 1 004,32 | 468 | 7 494,82 |
| Delivery Transportations (Cross-docking) | KEA Cross-dock; EDC Source | 97 342,00 | 302 | 80 360,83 |
| | KEA Cross-dock; CDC Source | 21 154,22 | 302 | 22 740,51 |
| | [ KEA Cross-dock; VL06O Local Source ] | 170,34 | 52 | 818,11 |
| | KEA Cross-dock Supply (EDC/CDC Source) (*) | 12 901,67 | 302 | 40 611,69 |
| | [ KEA Cross-dock Supply (VL06O Local Source) (*) ] | 15,69 | 52 | 1 269,42 |
| | **Total** | **461 311,21** | **6 914** | **606 671,96** |

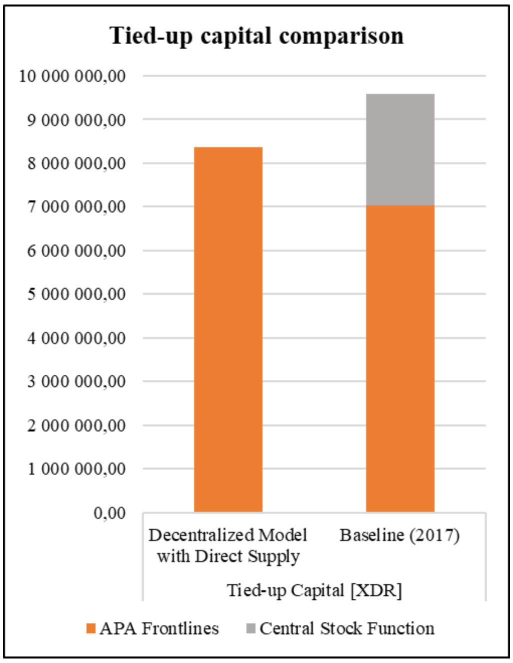
(*) KEA Cross-dock Supply refers to the cross-docked material flow from KEA Cross-dock to NZ FL (202)

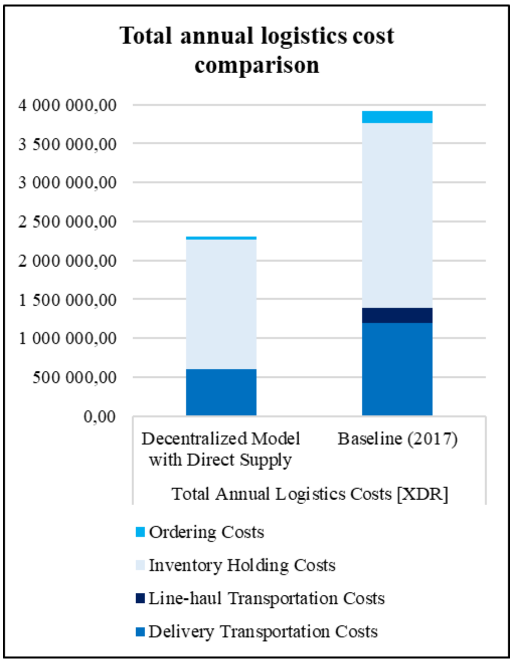
As a wrap up, Table 28 below summarizes the key figures of the scenario from a senior management point of view and presents these in comparison to the “Baseline (2017)”. As can be seen, the network structural changes done in the scenario have again brought visible improvements in comparison to the current state. The most notable observation is again a significant decrease in total logistics costs (-1 607 833,48 XDR / -41%), which is even slightly higher than in the benchmarking “Baseline (Optimized)” scenario. This is mainly due to the rationalization of supplying, but in this scenario also simplification of the warehouse structure and streamlining operations play a major role in the whole. Refinement and optimization of warehouses across the network has likewise reduced the capital employed to these (-1 223 224,63 XDR / -13%) as well as improved inventory turnover ratios (+217%). However, compared with the previous “Baseline (Optimized)” scenario and its benchmarks, this direct supply scenario ties up a little bit more capital in the system and since this is focusing only on the frontlines’ NDCs the average turnover ratio in APA area somewhat weakens which further impacts negatively to the capital efficiency. As in the previous scenario, the improved service levels in the APA area frontlines’ NDCs (70,11%→92,56%) will again allow for much better responsiveness, value creation and customer satisfaction, which is reflected not only in the facing fill rates, but also in the probabilities of stockout situations and related annual inefficiency costs which will decrease significantly (-1 443 854,98 XDR / -77 %). Since the same design basis and parameters have again been used in this "Decentralized Model with Direct Supply" scenario, the registered service levels and hence the inefficiency ratios are equal to the previous "Baseline (Optimized)" scenario.

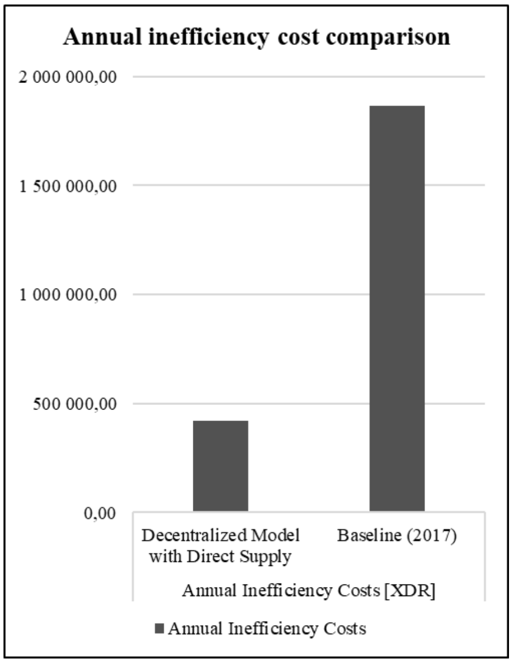
**Table 28. Summarization and comparison of distribution management figures in the Decentralized Model with Direct Supply scenario**

*Management Figures - APA area Distribution*

| Scenario | Decentralized Model with Direct Supply | Baseline (2017) | | Change in Comparison to the Baseline (2017) | |
|---|---|---|---|---|---|
| Tied-up Capital [XDR] | 8 368 113,72 | 9 591 338,35 | | -1 223 224,63 | -13 % |
| Total Annual Logistics Costs [XDR] | 2 304 379,70 | 3 912 213,18 | | -1 607 833,48 | -41 % |
| Annual Inefficiency Costs [XDR] | 422 530,24 | 1 866 385,22 | | -1 443 854,98 | -77 % |
| (*) Service Levels (SLc) [%] | **APA Frontlines** | **APA Frontlines** | **ADC** | **APA Frontlines** | **Central Stock Function** |
| | 92,56 % | 70,11 % | 83,00 % | 22,45 pp | N/A |
| Inventory Turnovers | **APA Frontlines** | **APA Frontlines** | **ADC** | **APA Frontlines** | **Central Stock Function** |
| | 0,96 | 0,30 | 1,60 | 217 % | N/A |
| (*) pp stands for percent point | | | | | |



## 8.3 What-if scenario C: China Centralization Model

The third what-if scenario to be reviewed is a more hybrid like “China Centralization Model” scenario. The basic idea when starting to build this scenario was the interest to test what the situation would look like, if the regional distribution center was moved from Singapore to China and hence the APA area would be served centrally from there. This idea was supported by numerous factors, such as the facts that a significant part of the globally distributed items come from China, China has a notably lower price level than Singapore and that in the immediate vicinity of China locates one major target market, HK. For these reasons the idea was brought to the modeling level, resulting in the scenario that to be presented next.

At the network level, the “China Centralization Model” scenario is built in the same way as the current state from two GDCs (EDC and CDC) acting as supply sites, one RDC centrally serving the APA distribution area and the APA area frontlines’ NDCs which are again the endpoints for this higher-level global distribution. As a change to the previous scenarios, however, the RDC is now located in China (more precisely one of its numerous Bonded Logistics Parks in the Free Trade Zone), where the materials allocated to the APA area is partly transported from EDC, while the other part comes directly from Chinese suppliers under the control of CDC. From the RDC (Bonded Regional Stock) the materials are further distributed to the target countries according to the need. Figure 29 below illustrates the described distribution network structure of this “China Centralization Model” scenario as well as the global material flows within it. Again, although not depicted in the figure APA area frontlines are also running their local sourcing in addition to the illustrated global distribution, which has been considered in the planning of the NDCs. At the same time all stocks and transportations in the network have been redesigned, which will be further discussed next.

As was outlined, in the scenario the RDC was mounted at a Bonded Logistics Park in China, which in general are industrial logistics zones formed by the government to facilitate cross-border trade (C.H. Robinson 2017, pp. 6; Inbound Logistics 2005). Bonded Logistics Parks combine both bonded land and international logistics infrastructure and are treated as being outside of the Chinese customs area so that transactions between companies inside and outside the zone are treated as import-export (China Briefing 2015, pp. 11; Inbound Logistics 2005).

Bonded Logistics Parks are in a preferential position in the eyes of Chinese government and they are designated to provide tax and other incentives to foreign trade companies (Inbound Logistics 2005). By availing these, import-export related taxes and customs duties (GST) along with the extra bureaucracy hindering the use of China as an international transfer, consolidation and sourcing hub can largely be avoided or at least diminished. Therefore, from the foreign trade point of view the set Bonded Regional Stock (China) is pretty close to the current state's ADC (Singapore) by allowing duty free cross-border operation, immediate tax refunds and other incentives while streamlining the collaboration with both customs and government. (China Briefing 2017; C.H. Robinson 2017, pp. 6; Inbound Logistics 2005)

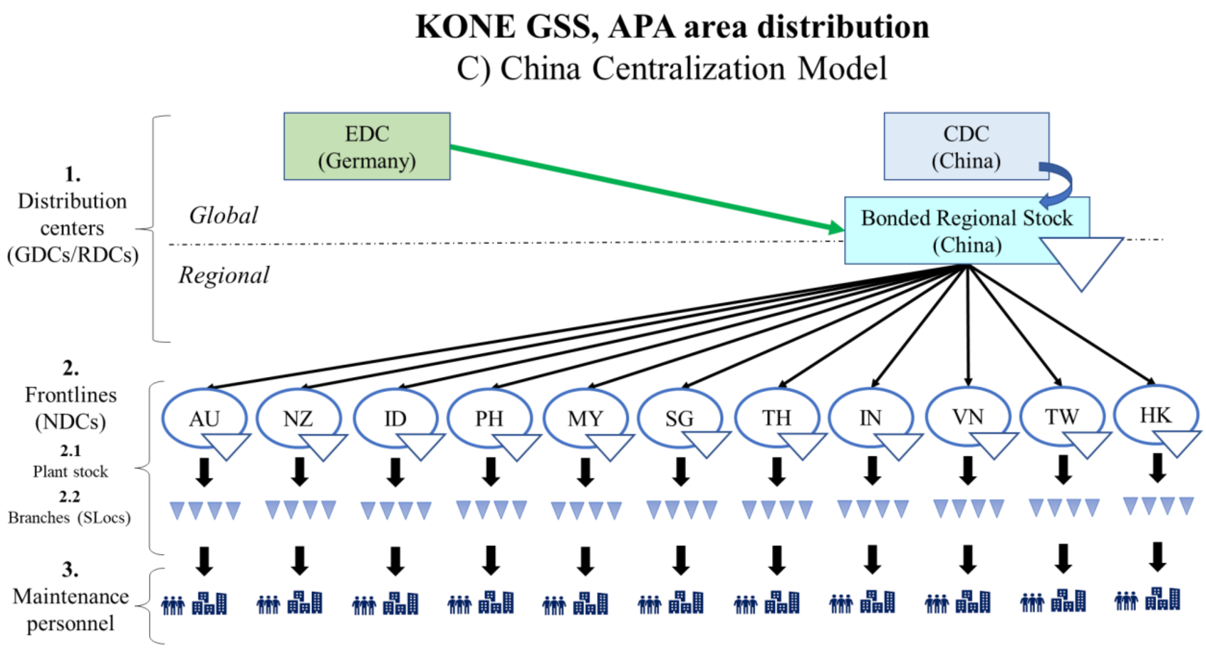



**Figure 29. Illustration of the China Centralization Model scenario in KONE GSS' APA area distribution**

As for the geographic placement, the Bonded Regional Stock (China) is ostensibly located in the Shanghai-Suzhou heartland area, where there are several bonded logistics centers operating under the above-mentioned scheme in place. Hence, the distance from China's global DC (Kunshan) will be moderate regarding the direct sourcing controlled by the CDC as well as other possible cooperation between these two. As was stated, in the scenario the CDC origin items allocated to the APA area are also conducted into the Bonded Regional Stock. This is done, as it is the only secure way to ensure that both EDC and CDC origin parts can be included in the same delivery due to the required export customs clearance and its well-known intricacy (Gebauer et al. 2011, pp. 751-752; Inbound Logistics 2005). Hence in the light of materials, the Bonded Regional Stock includes the same globally distributed items as the ADC in the "Baseline (Optimized)" scenario, excluding the ADC's locally sourced items (i.e. VL06O Local) which in the scenario will be directly supplied to the target countries. In warehouse planning, Bonded Regional Stock's service level was alike left the same as in ADC of the current state, as it was seen that a larger regional central stock will not have any greater added value given the RDC's assisting role in the cost-effective replenishment and service of the APA area frontlines' NDCs. In the light of costs, the operating costs of the Bonded Regional Stock have been estimated as a relative cost based on the known costs of the non-bonded CDC, given that the rent of a bonded stock is usually ~15% more expensive than non-bonded stock's one (situation in 2010). However, as bonded stock rents have expectedly risen in recent years due to the increased demand (the price difference can easily be doubled) and as the current storage contract for CDC is pretty favorable for the case company, the additional percentage was decided to set to 40% according to the principle of prudence. (SCMP 2015)

Since one of the assumptions made at the beginning of the what-if scenario analysis phase was that the supply sites (EDC and CDC) source and store the items supplied from these, in the "China Centralization Model" scenario there was no sense presenting the CDC origin items' entries doubled and thus provide false information. Because of this, it was decided to deduct the CDC origin items' capital effect as well as the part of the costs that is incurring in the non-bonded stockholding of China's global DC (where the items are stored in the rest of the scenarios) from the scenario, so that the network alternatives are consistent and hence fully comparable. Another option would be to add the estimated EDC and CDC inventories separately to each scenario and take the issue into account this way, but this would already be a much more laborious thing to do. The following Table 29 summarizes Bonded Regional Stock's key figures in the "China Centralization Model" scenario grouped into three data groups, which are *stocking data*, *inventory operative data* and *operating cost data*.

**Table 29. Key figures of Bonded Regional Stock (China) central stock function in the China Centralization Model scenario**

| | | Bonded Regional Stock (China) | | |
|---|---|---|---|---|
| **Data Group** | **Key Figure** | **EDC Origin** | **CDC Origin** | **Total (Deducted)** |
| Stocking Data | Onhand [pcs] | 49 914 | 35 670 | |
| | Onhand [XDR] | 991 110,01 | 187 372,12 **(-187 372,12)** | **991 110,01** |
| | Total Annual Fcast [pcs] | 210 039 | 136 680 | |
| | Total Annual Fcast [XDR] | 5 034 556,79 | 974 571,65 | |
| | Orders During Year [orders] | 4 807 | 2 126 | |
| Inventory Operative Data | Weighted AVE SLc [%] | **83,00 %** | | |
| | AVE Inventory Turnover | **2,50** | | |
| Operating Cost Data | Total Operating Costs [XDR] | 299 497,29 | 125 706,31 **(-98 765,25)** | **326 438,35** |
| | Holding Costs [XDR] | 292 020,48 | 122 399,53 **(-95 458,47)** | 318 961,54 |
| | Ordering Costs [XDR] | 7 476,81 | 3 306,78 **(-3 306,78)** | 7 476,81 |
| | Total Duty Payable [XDR] | - | - | - |

When it comes to comparison between the scenario alternatives, in this “China Centralization Model” scenario the RDC seems to tie up significantly lesser capital than the one in the previous “Baseline (Optimized)” scenario, which is mainly due to advantages stemming from the direct China sourcing. The same is also noticeable in terms of material circulation as well as operating costs, where the cost difference is further leveraged by the lower price level of China. Thus, the costs incurred are more moderate than in the “Baseline (Optimized)” scenario, however, the difference is not after all that massive as can be seen from the above table.

As in previous scenarios, the APA frontlines’ NDCs have also been cleansed and optimized in this “China Centralization” scenario in accordance with the principles outlined earlier. Once again, the main emphasis of the warehouse network has been shifted closer to consumption, that is in the NDCs, by relieving intermediate warehousing in the network while raising the NDCs’ stockholding and service levels as a whole closer to the industry standards, with the aim of ensuring high availability and rapid local deliveries whenever spare parts are needed. At the same time, attention was paid to NDCs’ operational performance and their effective replenishment. However, as the replenishments have now been shifted to a greater extent to more economical yet slower sea freight, which is also more susceptible to delays, small additional safety reserves have been erected for each NDC to safeguard against potential replenishment or delivery difficulties. Since the distances and thus the replenishment lead times have, though, been increased to some of the target countries, it was decided to increase the size of the additional reserves to 2 MOS. In addition to this, the increased lead times are also affecting to the warehouse bases as well as stock levels, what for compared with the "Baseline (Optimized)" scenario the country level stocks are tying up more capital and incurring more costs annually. The same is also reflected in the inventory turnovers, which seem to be more moderate in the scenario. Table 30 below summarizes the key figures of APA area frontlines' NDCs in the "China Centralization Model" scenario divided into four data groups, which are *stocking data*, *inventory operative data*, *operating cost data* and *inventory inefficiency data*.

**Table 30. Key figures of APA area frontlines' NDCs in the China Centralization Model scenario**

| Data Group | Key Figure | APA area Frontlines |
|---|---|---|
| Stocking Data | Onhand [pcs] | 749 550 |
| | Onhand [XDR] | **7 713 653,92** |
| | Total Annual Fcast [pcs] | 1 462 361 |
| | Total Annual Fcast [XDR] | 12 676 515,79 |
| | Orders During Year [orders] | 19 540 |
| Inventory Operative Data | Weighted AVE SLc [%] | **92,56 %** |
| | AVE Inventory Turnover | **1,00** |
| Operating Cost Data | Total Operating Costs [XDR] | **1 420 352,10** |
| | Holding Costs [XDR] | 1 389 959,59 |
| | Ordering Costs [XDR] | 30 392,52 |
| Inventory Inefficiency Data | Theoretical Stockouts [occasions] | 10 732 |
| | Total Annual Stockout Costs [XDR] | **422 530,24** |

As was noted above, in the "China Centralization Model" scenario's transits have been shifted into this pure two-stage system, where the "EDC-Bonded Stock China" line represents line-hauling and the "China Centralized Supply" from this Bonded Stock China to the APA area frontlines delivering. Consequently, in the system will be saved from the line-haul transportation coming from China, as CDC origin items are sourced directly into the RDC, which in turn lowers the overall transportation need. As for costing, the established EDC-CDC line-haul line of the scenario has a fairly preferential freight rate, which reduces the line-haul transportation costs in comparison to the current network. However, in the scenario the lengthened distances in delivering seem to increase costs here. As the two are summoned, in total the transportation costs are nonetheless somewhat more moderate in comparison with the "Baseline (Optimized)" scenario. Table 31 below illustrates transportations in this "China Centralization Model" scenario as well as related key figures broken down into line-hauling and delivering. As can be seen from the table, in the scenario's transportation planning has also minded the Local items joining the global distribution flow (i.e. VL06O Local), which are again ostensibly delivered from the ruins of ADC to the countries once a week via express parcel to get the transportation needs to match between the scenarios. As for the operational side of the transportations, the supplying (both line-hauling and delivering) here follows the same consolidation combined with the parallel multimodal use of transportation modes procedure in accordance with the "80/20 rule" as in previous scenarios. This brings the needed systemicity and manageability to the material flows while also allowing cost-effective implementation.

**Table 31. Transportation key figures of APA area distribution in the China Centralization Model scenario**

| | | Total Weight [kg] | Number of Shipments [pcs] | Total Transportation Costs [XDR] | |
|---|---|---|---|---|---|
| Delivery Transportations | China Centralized Supply | 447 219,19 | 3 322 | 364 021,51 | |
| | ( VL06O Local Supply ) | 1 174,66 | 572 | 8 730,27 | |
| | **Total (Intermediate Result)** | **448 393,85** | **3 894** | **372 751,79** | (A) |
| Line-haul Transportations | Bonded Stock China; EDC Source | 302 207,53 | 104 | 101 089,34 | |
| | **Total (Intermediate Result)** | **302 207,53** | **104** | **101 089,34** | (B) |
| | **Total** | **750 601,38** | **3 998** | **473 841,12** | (A+B) |

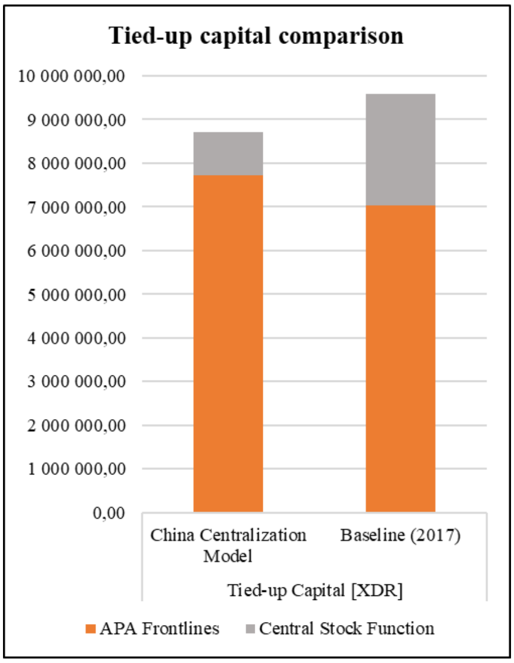
As a wrap up, the following Table 32 summarizes the key figures of the scenario from a senior management point of view and presents these in comparison to the “Baseline (2017)”. As can be seen, the above measures have again brought a swarm of development to the current state as well as raised interesting issues regarding the network analysis. As in previous scenarios, the most significant change is the sharp decline in total logistics costs (-1 691 581,60 XDR / -43%). Compared with the presented scenarios, the decline is yet notably higher than in the previous ones, which is largely due to radical changes in stockholding as well as the revised supply and sourcing procedures. Likewise, the remodeling of the transportation system and consequent waste minimization within the material flows has had a notable effect on the costs incurring. The performed stock clearance and optimization across the network have also lowered capital committed to these (-886 574,42 XDR / -9%) as well as improved the material circulation (APA Frontlines +227% / Central Stock Function +56%) in the network. Due to the heavier stock bases of the frontlines’ NDCs, the capital related figures are, though, far behind the leading “Baseline (Optimized)” scenario’s benchmarks. This in turn is because of the increased distances and hence extended replenishment lead times within the distribution area, which has increased the need for hold stock in the APA frontlines. On the contrary, the RDC’s lighter storage ties up less (registered) capital compared with the “Baseline (Optimized)” and is also outright smaller, which makes it operate more efficiently. However, this is not enough to make the entirety smaller than in the "Baseline (Optimized)" benchmark scenario. As in the previous scenarios, the improved service levels in the APA area frontlines' NDCs (70,11%→92,56%) will again produce much better responsiveness, value creation and customer satisfaction, which is reflected not only in the facing fill rates, but also in the probabilities of stockout situations and related annual inefficiency costs which will decrease significantly (-1 443 854,98 XDR / -77 %). Since the same design basis has again been utilized in this scenario, the service ability indicators are alike between the what-if scenarios.

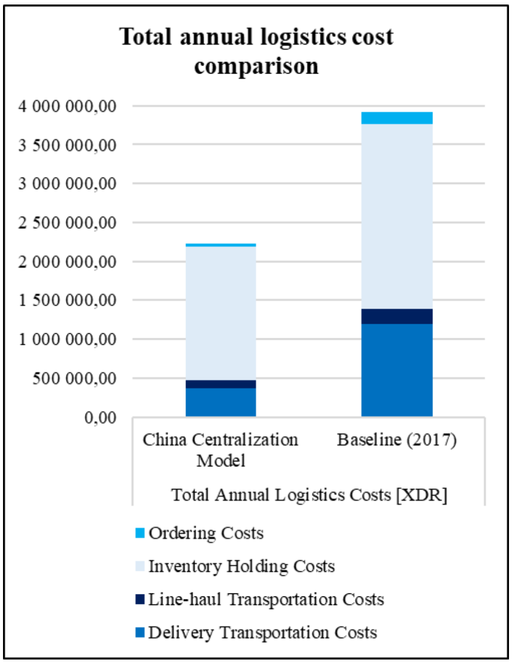
**Table 32. Summarization and comparison of distribution management figures in the China Centralization Model scenario**

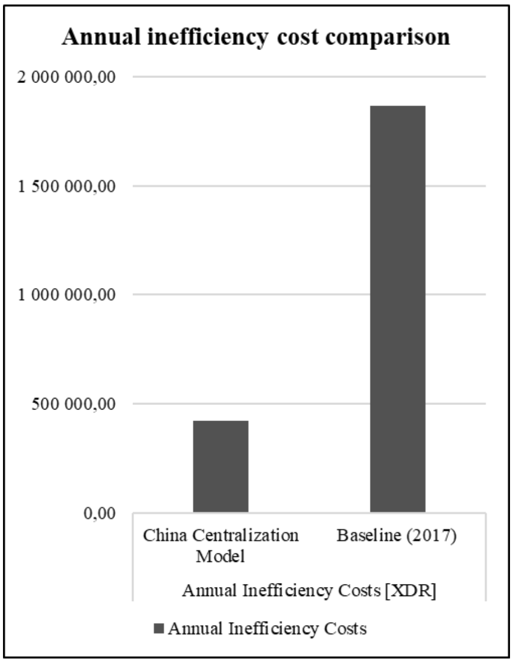
*Management Figures - APA area Distribution*

| Scenario | China Centralization Model | | Baseline (2017) | | Change in Comparison to the Baseline (2017) | |
|---|---|---|---|---|---|---|
| Tied-up Capital [XDR] | 8 704 763,93 | | 9 591 338,35 | | -886 574,42 | -9 % |
| Total Annual Logistics Costs [XDR] | 2 220 631,58 | | 3 912 213,18 | | -1 691 581,60 | -43 % |
| Annual Inefficiency Costs [XDR] | 422 530,24 | | 1 866 385,22 | | -1 443 854,98 | -77 % |
| (*) Service Levels (SLc) [%] | **APA Frontlines** | **Bonded Stock China** | **APA Frontlines** | **ADC** | **APA Frontlines** | **Central Stock Function** |
| | 92,56 % | 83,00 % | 70,11 % | 83,00 % | 22,45 pp | 0,00 pp |
| Inventory Turnovers | **APA Frontlines** | **Bonded Stock China** | **APA Frontlines** | **ADC** | **APA Frontlines** | **Central Stock Function** |
| | 1,00 | 2,50 | 0,30 | 1,60 | 227 % | 56 % |

(*) pp stands for percent point



## 8.4 What-if scenario D: ADC-China Hybrid Model

The fourth and final what-if scenario to be covered is "ADC-China Hybrid Model" scenario. The basic idea behind the development of this scenario was the desire to capture the best structural elements of the previously presented alternatives and to strive to embed these in the best possible way to one mixed hybrid model, that would produce a suitable network solution for our somewhat intricate distribution case. In this hybrid scenario, the regional ADC Central Stock of the "Baseline (Optimized)" scenario was combined with the emerged opportunity to make better use of China as a centralized distribution point for the APA area, which in turn was inspired by the "China Centralization Model" scenario. From a material point of view, in the scenario the EDC and CDC specific material flows were addedly separated and treated as individual entities, which was inspired by the "Decentralized Model with Direct Supply" scenario. Consequently, in this mixed hybrid alternative all the encountered pitfalls hindering the previous alternatives could be avoided and turned into the spearheads of development, while at the same capturing some new opportunities. On the paper, this scenario seemed very promising, and therefore the idea was modeled in order to see what the scenario would look like in the light of numbers.

At the network level, the "ADC-China Hybrid Model" scenario is afresh constructed from the two GDCs (EDC and CDC) acting as supply sites, one RDC centrally serving the APA distribution area (ADC Central Stock) and the APA area frontlines' NDCs which are again the endpoints for this higher-level global distribution. As was stated, in the scenario the material flows were separated and treated as individual entities. This was done by allocating the ADC completely to the use of EDC origin items while supplying CDC origin items directly from China. Here the idea is simply to bring the supply sites closer to the service area in the form of Singapore DC (ADC) and China DC (CDC), which will then serve as regional central stocks for the APA area and deliver goods directly to countries according to needs. Hence, the substantial intermediate stockholding, the unnecessary shipment of material as well as the high-cost long-haul delivering can be avoided while making better use of all available facilities and serving the scattered distribution area more effectively. The following Figure 30 illustrates the described distribution network structure of this "ADC-China Hybrid Model" scenario as well as the global material flows within it. Again, although not depicted in the figure APA area frontlines are still running their local sourcing in addition to the illustrated global distribution, which has been considered in the planning of the NDCs. At the same time all stocks and transportations in the network have been redesigned, which will be reviewed next.

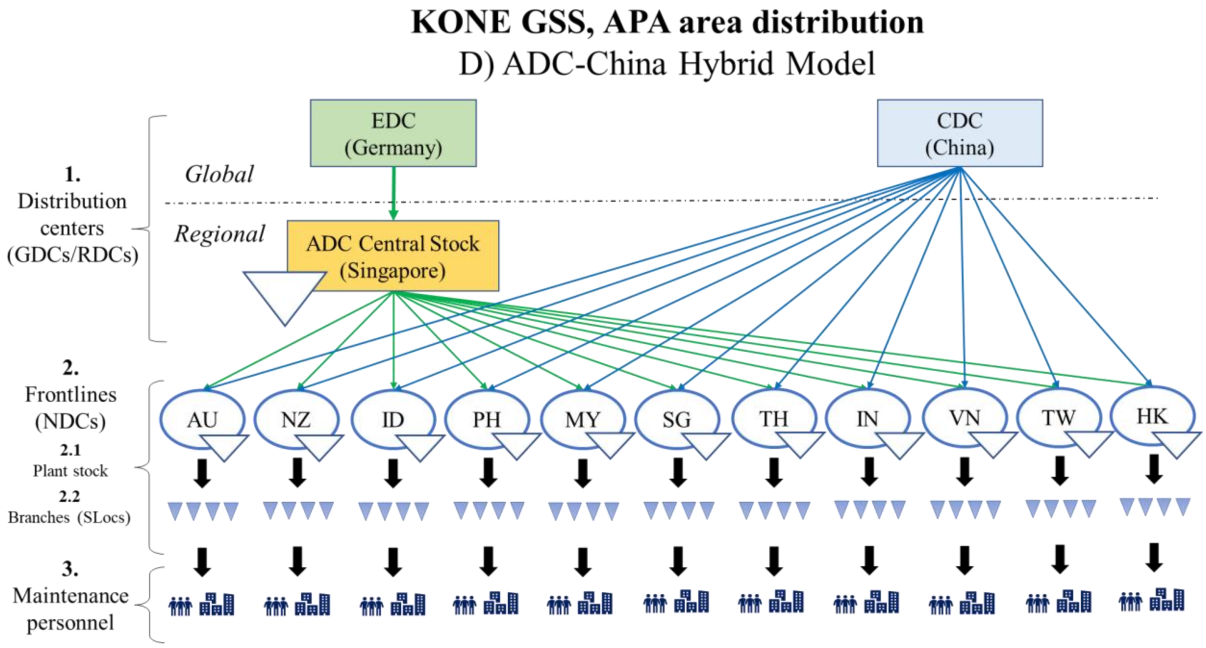



**Figure 30. Illustration of the ADC-China Hybrid Model scenario in KONE GSS' APA area distribution**

As was noted above, in the scenario the main RDC (ADC Central Stock) is set up in Singapore, which due to its central location (close to the alleged demand center of gravity) turned out to be a more favorable place for a centralized waypoint than China, regardless the known price difference between these two. In the network the ADC, which operates under the MES scheme at the same service level as before, stores the EDC origin items and the locally sourced VL06O Local items, while the CDC origin items have been kept in the CDC and distributed directly from there. Hence, overlapped stockholding could be reduced while also streamlining the warehouse structure. This hybrid-like network configuration was ended up because of:

i. *The distribution area to be served is relatively wide and scattered with a high dispersion of demand, which according to the previously presented findings advocates at least some form of direct delivering in order to serve the whole area cost-effectively while being able to cherish capital efficiency.*

ii. *According to conducted analyses, the equipment base within the frontlines seemed to be such as the need for CDC materials is relatively higher close to the immediate sphere of influence of China than elsewhere in the service area. For EDC materials, the case is somewhat opposite, but here the difference is significantly more moderate and thus items should be available equally everywhere.*

iii. *Storing CDC origin items regionally in a centralized manner and the additional transits needed to enable this, did not seem to bring the desired added value for the money spent. Hence, it would be a good idea to strive to abandon this by separating the material flows and starting direct supplying from China.*

iv. *By bringing the European supply site closer to the APA area in the form of a centralized waypoint (ADC), average delivery distances as well as replenishment lead times could be significantly reduced. This in turn enables implementing this part of the global distribution chain in an effective yet efficient manner while also harnessing the aforesaid direct delivering.*

v. *The outlined hybrid layout is more than ready to support the previously highlighted idea of "concentrating items regionally in a central stock function". In the scenario, this centralization could be done for instance partly to the ADC (EDC origin items) and partly to the CDC (CDC origin items).*

As for the central stock function performance of this hybrid layout, the following Table 33 summarizes ADC's key figures in the "ADC-China Hybrid Model" scenario divided into three data groups, which are *stocking data*, *inventory operative data* and *operating cost data*. As can be seen from the table, the capital employed in intermediate stockholding and the related operating costs have been decreased significantly compared with both the current state and the benchmarking "Baseline (Optimized)" scenario. The same development is likewise reflected in the material circulation, which in the bigger picture allows for more capital efficient running of the distribution network and hence cherishing both operational and financial performance of the system.

**Table 33. Key figures of ADC (Singapore) central stock function in the ADC-China Hybrid Model scenario**

| Data Group | Key Figure | ADC Central Stock (Singapore) |
|---|---|---|
| Stocking Data | Onhand [pcs] | 56 437 |
| | Onhand [XDR] | **1 087 058,32** |
| | Total Annual Fcast [pcs] | 211 664 |
| | Total Annual Fcast [XDR] | 5 097 536,59 |
| | Orders During Year [orders] | 4 283 |
| Inventory Operative Data | Weighted AVE SLc [%] | **83,00 %** |
| | AVE Inventory Turnover | **2,51** |
| Operating Cost Data | Total Operating Costs [XDR] | **401 389,76** |
| | Holding Costs [XDR] | 394 727,98 |
| | Ordering Costs [XDR] | 6 661,78 |
| | Total Duty Payable [XDR] | - |

Like in previous scenario alternatives, the NDC stocks of the APA area frontlines have also been refined and optimized in this scenario in accordance with the previously described principles. The objective of warehouse network design has yet been to shift the emphasis of stockholding closer to consumption, by relieving intermediate warehousing in the network while raising the NDCs' stockholding and service ability closer to the industry standards. At the same time, attention was paid to the efficient operation and replenishment of stocks. However, as the replenishments have now been shifted to a greater extent to sea freight which tends to be more prone to delays, small additional safety reserves have been set for each NDC to secure against any potential replenishment or delivery difficulties. As the lead times to each frontline have yet been prolonged due to the changes in the network structure, the sizing of the safety reserves had to be rethought. Based on the previous scenarios and their already done resolutions, for items to be supplied from ADC the safety reserve was decided to set against 1 MOS and for CDC items against 2 MOS. In addition to this, the increased lead times are also affecting to the warehouse bases and stock levels, what for compared with the "Baseline (Optimized)" scenario the country level stocks are as a whole tying up slightly more capital and thus incurring more costs annually. However, there are quite significant regional differences in this. As a result, material circulation in APA area frontlines' NDCs is on average a somewhat better than in the "Baseline (Optimized)" because regional efficiency disparities have been leveled. Table 34 below summarizes the key figures of APA area frontlines' NDCs in the

"ADC-China Hybrid Model" scenario divided into four data groups, which are *stocking data*, *inventory operative data*, *operating cost data* and *inventory inefficiency data*.

**Table 34. Key figures of APA area frontlines' NDCs in the ADC-China Hybrid Model scenario**

| Data Group | Key Figure | APA area Frontlines |
|---|---|---|
| Stocking Data | Onhand [pcs] | 725 184 |
| | Onhand [XDR] | **7 029 874,80** |
| | Total Annual Fcast [pcs] | 1 462 361 |
| | Total Annual Fcast [XDR] | 12 676 515,79 |
| | Orders During Year [orders] | 19 974 |
| Inventory Operative Data | Weighted AVE SLc [%] | **92,56 %** |
| | AVE Inventory Turnover | **1,11** |
| Operating Cost Data | Total Operating Costs [XDR] | **1 270 595,74** |
| | Holding Costs [XDR] | 1 239 528,18 |
| | Ordering Costs [XDR] | 31 067,56 |
| Inventory Inefficiency Data | Theoretical Stockouts [occasions] | 10 732 |
| | Total Annual Stockout Costs [XDR] | **422 530,24** |

As was noted above, in the "ADC-China Hybrid Model" scenario's transits have been shifted to a radically renewed two-channel system, where EDC and VL06O Local items are distributed through a transportation chain where "EDC-ADC Central Stock" line-hauling is combined with "ADC Centralized Supply" delivering, while CDC items are distributed to the APA area via direct delivering i.e. "CDC Direct Supply". Through this, the unnecessary transfer of materials in the distribution area is being cut off, which from an efficiency point of view is a valuable thing. At the same time, it is possible to grasp the potential savings of direct supplying, which is a road to a more cost-effective regional distribution (especially as the country level demands and hence average delivery volumes are forecasted to increase significantly in the future). This increased direct delivering has however shifted cost incurring and hence the cost structure a fraction more to the transportation side. As a result, the transportation costs are expectedly higher than in the "Baseline (Optimized)" scenario with the prevailing demand. This is, though, considerably lesser than that of the current state. When it comes to the operational side of transportations, the supplying (both line-hauling and delivering) follows again the same consolidation combined with the parallel multimodal use of transportation modes procedure in accordance with the "80/20 rule" as in previous scenarios. The following Table 35 illustrates the transportation key figures of this "ADC-China Hybrid Model" scenario broken down into line-hauling and delivering.

**Table 35. Transportation key figures of APA area distribution in the ADC-China Hybrid Model scenario**

| | | Total Weight [kg] | Number of Shipments [pcs] | Total Transportation Costs [XDR] | |
|---|---|---|---|---|---|
| Delivery Transportations | ADC Centralized Supply | 303 382,19 | 3 322 | 255 457,44 | |
| | CDC Direct Supply | 145 011,66 | 3 322 | 199 597,20 | |
| | **Total (Intermediate Result)** | **448 393,85** | **6 644** | **455 054,64** | (A) |
| Line-haul Transportations | ADC Central Stock; EDC Source | 302 207,53 | 104 | 120 276,25 | |
| | **Total (Intermediate Result)** | **302 207,53** | **104** | **120 276,25** | (B) |
| | **Total** | **750 601,38** | **6 748** | **575 330,89** | (A+B) |

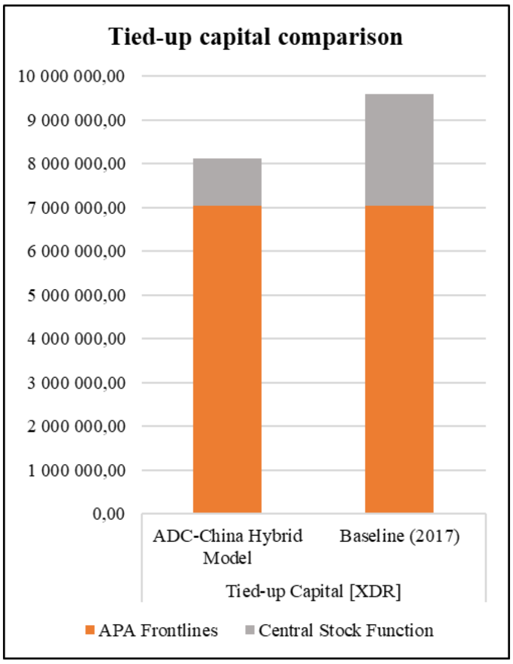
As a wrap up, Table 36 below summarizes the key figures of the scenario from a senior management point of view and presents these in comparison to the “Baseline (2017)”. As can be seen, the above-mentioned structural changes and development measures in the distribution network have once again brought a staggering step forward in terms of both effectiveness and efficiency in comparison to the current state. The most notable change is again the significant decrease in total logistics costs (-1 664 896,79 XDR / -43 %), which are somewhat at the same level as in the previous low-cost “China Centralization” scenario. As has already been underlaid, this is due to the rationalization of material flows and transportation planning combined with deliberated changes in the warehouse structure as well as the revised supply and sourcing procedures, which has minimized waste within the distribution network as well as inhibited costs incurring. Streamlining the distribution network, combined with the refinement and optimization of stocks, has likewise reduced the capital committed into the network (-1 474 405,22 XDR / -15 %), which in turn is around at the same level with the leading “Baseline (Optimized)” scenario. In addition to this, the overall material circulation (APA Frontlines +264 % / Central Stock Function +57 %) in the network has also improved remarkably. When analyzing the network more closely, it can be seen that in terms of APA area frontlines’ NDCs the capital invested in warehouses is slightly larger than in the “Baseline (Optimized)” scenario due to the extended distances within the network, but because the development measures have leveled regional efficiency disparities in the network, this has resulted in a slight improvement in the average turnover rate of APA frontlines. Instead, the considerably lighter stock base of the central stock function ties up lesser capital and makes it operate far more efficiently than that of the “Baseline (Optimized)” scenario, which is also reflected in the corresponding figures.

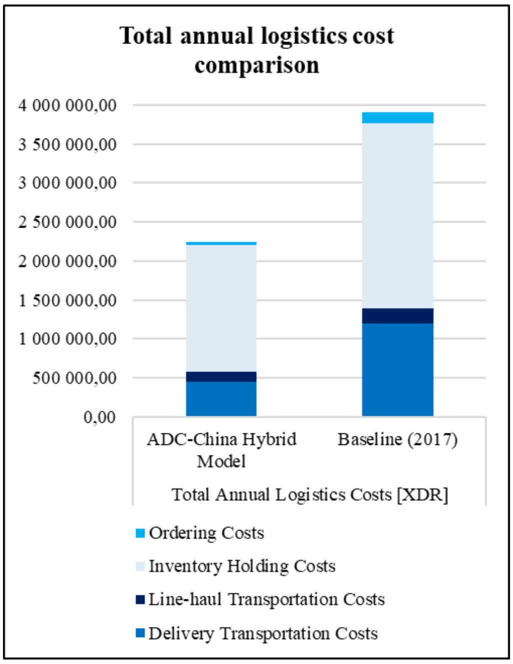
All in all, based on the presented results it can be stated that the scenario has done what was hoped and perhaps even more. As in previous scenarios, shifting the focus of stockholding to a greater extent to the APA area frontlines' NDCs and consequent raised service levels (70,11%→92,56%) will again also enable better responsiveness, value creation and customer satisfaction. This is alike reflected in the probabilities of stockout situations and related annual inefficiency costs, which have decreased significantly compared with the current state (-1 443 854,98 XDR / -77 %). Since the same design basis and procedures have been used in every what-if scenario, the service ability indicators are uniform between these.

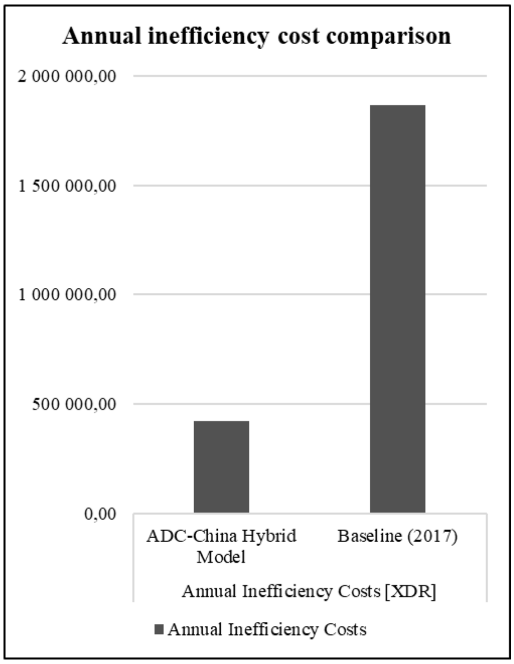
**Table 36. Summarization and comparison of distribution management figures in the ADC-China Hybrid Model scenario**

*Management Figures - APA area Distribution*

| Scenario | ADC-China Hybrid Model | | Baseline (2017) | | Change in Comparison to the Baseline (2017) | |
|---|---|---|---|---|---|---|
| Tied-up Capital [XDR] | 8 116 933,13 | | 9 591 338,35 | | -1 474 405,22 | -15 % |
| Total Annual Logistics Costs [XDR] | 2 247 316,39 | | 3 912 213,18 | | -1 664 896,79 | -43 % |
| Annual Inefficiency Costs [XDR] | 422 530,24 | | 1 866 385,22 | | -1 443 854,98 | -77 % |
| (*) Service Levels (SLc) [%] | **APA Frontlines** | **ADC Central Stock** | **APA Frontlines** | **ADC** | **APA Frontlines** | **Central Stock Function** |
| | 92,56 % | 83,00 % | 70,11 % | 83,00 % | 22,45 pp | 0,00 pp |
| Inventory Turnovers | **APA Frontlines** | **ADC Central Stock** | **APA Frontlines** | **ADC** | **APA Frontlines** | **Central Stock Function** |
| | 1,11 | 2,51 | 0,30 | 1,60 | 264 % | 57 % |
| (*) pp stands for percent point | | | | | | |



# 9 COMPARISON AND ANALYSIS OF THE WHAT-IF SCENARIOS

Now that the what-if scenario alternatives for distribution development have been described and modeled, the next step would be to delve into their results and performance, and to start to compare the options critically. As has already been noted, there began to emerge quite significant differences between the scenario alternatives in terms of the network components, but now the aim would be to move the look more to the whole and review the structural options purely from a senior management point of view to find the most prolific and operationally efficient distribution network structure to serve the APA area in the future. In this chapter, the scenarios are compared and analyzed against the following decision variables drawn from the literature:

*i.* *Service level provided by logistics* → Service ability analysis
*ii.* *Tied-up capital and related efficiency* → Capital efficiency analysis
*iii.* *Total annual logistics costs* → Cost-effectiveness analysis

At the end of the chapter, a three-piece future-oriented sensitivity analysis conducted as an additional part of the study along with its results is also presented. With this, the scenario alternatives and their key figures were further analyzed by pointing out how the scenarios and their "balances of power" would appear in the light of numbers if the key design inputs (*demand, transportation costs* and *warehousing costs*) were to change in one direction or another. At the same time, understanding about the robustness of the scenarios and what would be a potentially good solution for the future could also be raised.

## 9.1 Service level provided by logistics

The first decision variable to be reviewed in this scenario comparison and analysis is service level provided by logistics and consequent service ability in the networks. With respect to this, Table 37 below summarizes the service ability indicators of the scenario alternatives, which are the warehouse service level and the annual inefficiency costs. In the table, these figures are divided according to the underlying network structures in terms of APA area frontlines' NDCs as well as a possible intermediate central stock function. When it comes to the inner life of these indicators, the warehouse service level (i.e. the facing fill rate) reflects the probability that order lines can be fulfilled by the facing warehouse in question, and the inefficiency costs illustrate the approximated cost effects of annual stockouts. However, as the stockout cost is not a directly visible logistics cost for the case company but rather an indirectly realizable inefficiency cost, it was desired to distinguish this as a separate cost category and present it under service ability. The service ability indicators to be reviewed in this section are presented in terms of the prevailing demand and cost level.

**Table 37. Scenario comparison in terms of service level provided by logistics and consequent service ability**

| *Scenario Comparison and Analysis* *Service Ability* | | **A) Baseline (Optimized)** | **B) Decentralized Model with Direct Supply** | **C) China Centralization Model** | **D) ADC-China Hybrid Model** |
|---|---|---|---|---|---|
| **Service Level(s) (SLc)** | APA Frontlines [%] | **92,56 %** | **92,56 %** | **92,56 %** | **92,56 %** |
| | Central Stock Function [%] | **83,00 %** | **-** | **83,00 %** | **83,00 %** |
| **Annual Inefficiency Costs** | APA Frontlines [XDR] | **422 530,24** | **422 530,24** | **422 530,24** | **422 530,24** |

Observations on service ability in the scenario alternatives:

- By looking at the service ability indicators of the scenarios and comparing them to the current state (*APA Frontlines 70,11%* and *ADC 83,00%*), it is seen that in the scenarios have been taken a huge step forward in terms of the frontlines' service ability, while the service level of the potential intermediate central stock is maintained the same. This is since in the network design it was wanted to make a conscious change of focus closer to the consumption, that is in these frontlines' NDCs, in order to be more responsive and to be able to create better value for customers. As the local distribution is executed via express parcel through which parts can be delivered to every corner of the country on the same day, parts' availability is the biggest bottleneck in this chain, which has now been resolved. The large one-off increase in the service level is also strongly reflected in the annual inefficiency costs, which have now fallen to around one-fourth of the current level (*1 866 385,22 XDR*).
- As can be seen from the table, the service ability indicators between the scenarios are very similar, which is due to the identical inventory design basis and procedures used in modeling. This has been done in order to bring the scenario alternatives' service level characteristics into the same line and thus make it easier to compare the options. This consequently means that, with regard to service aspects, the scenario alternatives are capable of producing the same responsiveness as well as prospect of sales being made, and

so in the light of the numbers the superiority will have to be solved by the capital and cost factors, which are to be underwent next.

## 9.2 Tied-up capital and related efficiency in the distribution network

The second decision variable to be reviewed in this scenario comparison and analysis is tied-up capital and related efficiency in the distribution networks. With respect to this, the following Table 38 summarizes the capital efficiency indicators of the scenario alternatives, which are the tied-up capital and the inventory turnover ratios. In the table, the figures are again divided into APA area frontlines' NDCs as well as a possible intermediate central stock function according to the underlying network structures. When it comes to the inner life of these indicators, the tied-up capital reflects the stock-bound capital within the network and the inventory turnover ratios are illustrating the related material circulation expressed as "aggregating" mean values. The capital efficiency indicators to be reviewed in this section are presented in terms of the prevailing demand and price level.

**Table 38. Scenario comparison in terms of tied-up capital and related efficiency**

| *Scenario Comparison and Analysis* <br> *Capital Efficiency* | | A) Baseline (Optimized) | B) Decentralized Model with Direct Supply | C) China Centralization Model | D) ADC-China Hybrid Model |
|---|---|---|---|---|---|
| **Tied-up Capital** | APA Frontlines [XDR] | 6 883 646,23 | 8 368 113,72 | 7 713 653,92 | 7 029 874,80 |
| | Central Stock Function [XDR] | 1 302 373,55 | - | 991 110,01 | 1 087 058,32 |
| | Total Tied-up Capital [XDR] | **8 186 019,77** | **8 368 113,72** | **8 704 763,93** | **8 116 933,13** |
| **Inventory Turnover(s)** | APA Frontlines | **1,10** | **0,96** | **1,00** | **1,11** |
| | Central Stock Function | **2,27** | **-** | **2,50** | **2,51** |

Observations on capital efficiency in the scenario alternatives:

- By looking at the capital committed to network and its structure in the scenarios, it is seen that compared with the current state (*9 591 338,35 XDR*, divided as *APA Frontlines 7 030 384,54 XDR* and *ADC 2 560 953,81 XDR*) in the scenarios have been able to notably reduce the tied-up capital as a whole by refining the inventories and optimizing their operations from the point of view of the entire distribution chain. The done network-structural changes have also had a significant impact on the need for stockholding and thus on the commitment of capital. When it comes to the inventory turnover ratios, in comparison to the current state (*APA Frontlines ~ 0,30 / ADC ~ 1,60*) the efficiency of inventories has likewise improved, especially in the APA area frontlines' NDCs but also in the possible intermediate central stocks, which can be seen from the corresponding key figures. It is also worth noting that capital efficiency indicators have been tuned up, while at the same time increasing the service ability of the APA frontlines' NDCs as well as shifting the replacements to a greater extent to maritime.

- When looking at the tied-up capital situation between the scenarios, it can be found that the need for storage and thus the amount of committed capital is the greatest in the "Decentralized Model with Direct Supply" and "China Centralization Model" scenarios, which is largely due to extended distances and lead times within the distribution networks, which respectively increases the need for stockholding in the APA area frontlines. In addition to this, the "China Centralization Model" scenario also has a centralized intermediate stock as its "capital burden", which further increases the stock-bound capital. Instead the least amount of capital is committed to the "Baseline (Optimized)" and "ADC-China Hybrid Model" scenarios, where the warehouse structures have been designed and set so that the distances and hence the lead times can in a large extent be minimized in distribution. Between these the slight differences in capital commitment are stemming from the differences in the implementation of the intermediate warehousing and flows of material, which are further reflected in the stockholding needs. In the "ADC-China Hybrid Model" these are performed in a somewhat more efficient manner, which both reduces overlapped stockholding and streamlines the warehouse structure as a whole. Due to this, capital committed to the distribution network is the most moderate in this scenario. However, with prevailing demand the differences are not that great, but based on these some conclusions can already be drawn.
- As for material circulation, the above described are expectedly strongly reflected here as well. When looking at inventory turnover ratios more closely, it can be noted that as a whole the circularity is the weakest in the "Decentralized Model with Direct Supply" scenario, where direct supplying and consequent large inventories in APA area frontlines fundamentally impair material rotation. After this, the final order is more a matter of preferences. When comparing the "Baseline (Optimized)" and "China Centralization

Model" scenarios, the former achieves a better rotation in the frontlines due to lighter storage bases, while in the latter intermediate warehousing is more efficient due to China's direct sourcing and hence lower replacement lead times, which reduces the need for stockholding to some extent (in terms of CDC items). From the viewpoint of material circulation, the best situation is by far in the "ADC-China Hybrid Model", where the top structural elements of the previous scenarios are embedded in the most suitable way to produce a distribution structure that can be at the same time both efficient and effective.

## 9.3 Total annual logistics costs of the distribution network

The third and final decision variable to be reviewed in this scenario comparison and analysis is total annual logistics costs and consequent cost-effectiveness in the networks. With respect to this, Table 39 below summons the annual logistics costs of the scenario alternatives while also illustrating the underlying cost structures. As can be seen, the logistics costs are composed of transportation and warehousing related costs, which divides further into network construction specific sub costs. When it comes to the inner life of these cost components, the warehouse operating costs cover all the annual operational costs associated with stockholding (holding costs and ordering costs) while the transportation costs cover all incurred costs related to meeting the annual transportation need. All the logistics costs to be reviewed in this section are presented with prevailing demand and cost level.

**Table 39. Scenario comparison in terms of total annual logistics costs and consequent cost-effectiveness**

| *Scenario Comparison and Analysis* | *Cost-Effectiveness* | **A) Baseline (Optimized)** | **B) Decentralized Model with Direct Supply** | **C) China Centralization Model** | **D) ADC-China Hybrid Model** | |
|---|---|---|---|---|---|---|
| **Logistics Costs** | Delivering [XDR] | 333 833,96 | 606 671,96 | 372 751,79 | 455 054,64 | |
| | Line-hauling [XDR] | 165 461,07 | - | 101 089,34 | 120 276,25 | |
| | Transportation Costs [XDR] | 499 295,03 | 606 671,96 | 473 841,12 | 575 330,89 | (A) |
| | APA Frontlines [XDR] | 1 238 613,66 | 1 697 707,74 | 1 420 352,10 | 1 270 595,74 | |
| | Central Stock Function [XDR] | 590 066,48 | - | 326 438,35 | 401 389,76 | |
| | Warehouse Operating Costs [XDR] | 1 828 680,14 | 1 697 707,74 | 1 746 790,45 | 1 671 985,50 | (B) |
| | Total Annual Logistics Costs [XDR] | **2 327 975,17** | **2 304 379,70** | **2 220 631,58** | **2 247 316,39** | (A+B) |

<u>Observations on cost-effectiveness in the scenario alternatives:</u>

- By looking at the cost structures of the scenario alternatives and comparing these to the current state situation (*3 912 213,18 XDR*, divided as *transportation 1 393 487,04 XDR* and *warehouse operating 2 518 726,13 XDR*), it can be noticed that within the distribution network and its cost structure have been made a fundamental change of focus from the transportation side to a greater extent to warehousing. This both operational and structural change has allowed a significant drop in transportation costs while moderating the overall costs incurring. Of course, the activity-specific development measures and the network design work have also had their part in this remarkably cost drop, as these have further advanced the cost reduction as well as created opportunities to be more cost-effective for both now and especially in the future.
- When digging deeper into the cost structures of the scenarios, it can be seen that in terms of transportation costs the largest cost accumulation is, as can already be expected, in the "Decentralized Model with Direct Supply" scenario, which relies on direct supplying instead of intermediate stockholding. The second largest transportation cost accumulation is incurring in the "ADC-China Hybrid Model" scenario, which combines the direct supplying with regional central logistics. The lowest amounts of transportation costs are generated in the "China Centralization Model" and "Baseline (Optimized)" scenarios, which are based on a more centralized operating model. Here the material is initially transported as larger line-haul shipments in the distribution area and then distributed centrally to the target countries according to needs.
- Conversely with regard to warehousing, the largest cost accumulation is incurring in the "Baseline (Optimized)" scenario, which is mainly due to the large centralized intermediate stock (ADC). The second largest cost accumulation is in the "China Centralization Model" scenario, before the "Decentralized Model with Direct Supply" scenario. In these, prolonged distances and lead times accumulate both needed inventory and related costs within the distribution network (especially in the frontlines' NDCs). In the "China Centralization Model" scenario, there is also a regional intermediate stock, which further incurs costs, but more moderately than in other analogous scenario alternatives due to lower price level of China. The most moderate cost accumulation considering warehousing is in the "ADC-China Hybrid Model" scenario, where by combining the centralized intermediate

warehousing and direct supplying in an appropriate proportion, the need for storage and thus related costs can be reduced in the network.

- As the aforesaid are merged and the network is viewed as a whole, can be seen that the total annual logistics costs turn to be the smallest in the "China Centralization Model" and "ADC-China Hybrid Model" scenario alternatives, where by building a favorable balance between transporting and stockholding while rationalizing material flows and streamlining network structures, the accumulation of costs in the distribution system can be curbed with prevailing cost and demand levels. The largest total costs are instead in the so-called extreme scenarios, "Baseline (Optimized)" and "Decentralized Model with Direct Supply", where building the distribution system on one building block (in the "Baseline (Optimized)" scenario on warehousing and in the "Decentralized Model with Direct Supply" scenario on transporting) creates slight imbalances into the distribution network and its functionalities, which seem to result in a somewhat higher total annual logistics cost over the aforementioned scenario alternatives. However, in the prevailing situation the differences are not that great but based on these some conclusions can again already be drawn.

## 9.4 Future-oriented sensitivity analyses

The future-oriented sensitivity analyses performed during the study were done as one variable sensitivity analysis or in other words by using the OAT (one-at-a-time) method, whereby one input at a time was varied in one direction or another, while others remained constant. In this way, each scenario's sensitivity to key input changes could be detected by monitoring the outputs (in this case the key decision variables discussed above), while maintaining the comparability of the results as all the changes observed will be entirely due to single variable change. When reviewing the case company's distribution network and related key functions, the most important inputs regarding the future were seen to be: *demand*, *transportation costs* and *warehousing costs*. Hereby, these and their effects on future outlooks will be examined in the upcoming sensitivity analyses.

### 9.4.1 Demand sensitivity analysis

The first sensitivity analysis subset to be underwent is demand sensitivity. Table pair 40 and 41 below summon the results of this analysis, former in the light of logistics costs and the latter in the light of the commitment of capital, when demand is varied. As can be seen, the demand sensitivity analysis has been carried out from a rather growth-oriented point of view. This is because the case company's long-term projections suggest that sales and thus demand for spare parts in the APA area are expected to grow strongly in the coming years (especially in the emerging target markets). Although the growth forecasts are more moderate in the mature markets, the sensitivity analysis has been conducted by changing total demand. However, in the modeling tool built for the study it was made possible to change the demand parameters also on a country basis, but in order to withhold more accurate forecasts, no targeted review was included in the study.

As can be noted from the tables and related graphs depicting the demand sensitivity analysis, the “ADC-China Hybrid Model” scenario seems to be the best option to adapt to the changing demand, which thus will enable us to respond to increased demand now and in the future in a very cost-effective manner while also maintaining capital efficiency. This, as expected, originates from a well-designed network structure where the aim was to combine the very best of the different types of structural archetypes into the same embedded model, that would cherish both effectiveness and efficiency in the distribution. The second-best alternative to cope with changing demand is a somewhat surprisingly the current network structure, that is the “Baseline (Optimized)” scenario. With regard to this scenario, there is however the high cost burden of the current state, but if this be overlooked, the “Baseline (Optimized)” is quite competitive, especially with more modest changes in demand. For both of these, the good adaptability with changing demand can be explained by the utilization of ADC as a consolidating waypoint in the EDC materials’ distribution to the APA area, which ensures a cost-effective delivery arrangement for a significant material entity. At the same time, the distances and lead times to the target markets can be balanced and in part also minimized, which in turn helps to moderate stock-bound capital in APA area frontlines’ NDCs. As for the difference between these two, it can comparably be explained by the more efficient distribution of CDC materials in the “ADC-

China Hybrid Model" scenario, which makes it possible to reduce costs from the distribution chain while releasing stock-bound capital by rationalizing material flows.

Conversely, the weaker options for adapting changing demand seem to be the "Decentralized Model with Direct Supply" and "China Centralization Model" scenarios, the latter scenario being the weakest. This is because, in spite of the regional central warehouse, in the scenario distances and lead times to the distribution area increase compared with the analogous scenarios, which consequently in the long run increase the need for stockholding in frontlines' NDCs more than that of the previous scenarios. As this is merged with the regional central stock and its growing capital and cost implications, the effects of increasing demand will multiply. Then even the minimized transportation needs are not enough to turn the scale in the other direction. On the other hand, in the "Decentralized Model with Direct Supply" scenario growth in demand is a positive thing especially from the viewpoint of transportations, as this will increase the average delivery volumes, which in turn will enable more economical distribution in the longer run. The backbone of this scenario is, however, the heavy stocks in APA area frontlines' NDCs, which seem to tie up exponentially capital as demand keeps increasing.

As a conclusion, it can be stated that the "ADC-China Hybrid Model" scenario along with the "Baseline (Optimized)" scenario seem to be the best alternatives in terms of complying with increasing demand and are thus the most robust options for the future growth prospects. When it comes to the mutual valuation of these, the "Baseline (Optimized)" seems to work better with more moderate growth rates (0%→+100%), while the "ADC-China Hybrid Model" scenario is better over the longer term (+100%→+350%).

**Table 40. Demand sensitivity analysis in terms of total logistics costs**

| | -50% | 0% | +50% | +150% | +250% | +350% |
|---|---|---|---|---|---|---|
| A) Baseline (Optimized) | 1 599 152,83 | 2 327 975,17 | 3 050 876,84 | 4 420 995,76 | 5 714 742,63 | 6 960 963,10 |
| B) DM with DS | 1 665 402,35 | 2 304 379,70 | 2 917 407,05 | 4 093 571,94 | 5 202 829,93 | 6 344 448,05 |
| C) China Centralization | 1 550 613,58 | 2 220 631,58 | 2 906 593,33 | 4 233 317,93 | 5 508 389,96 | 6 721 477,83 |
| D) ADC-China Hybrid | 1 596 590,40 | 2 247 316,39 | 2 881 129,28 | 4 053 910,99 | 5 170 114,33 | 6 306 082,01 |
| Leading Scenario | "C" | "C" | "D" | "D" | "D" | "D" |

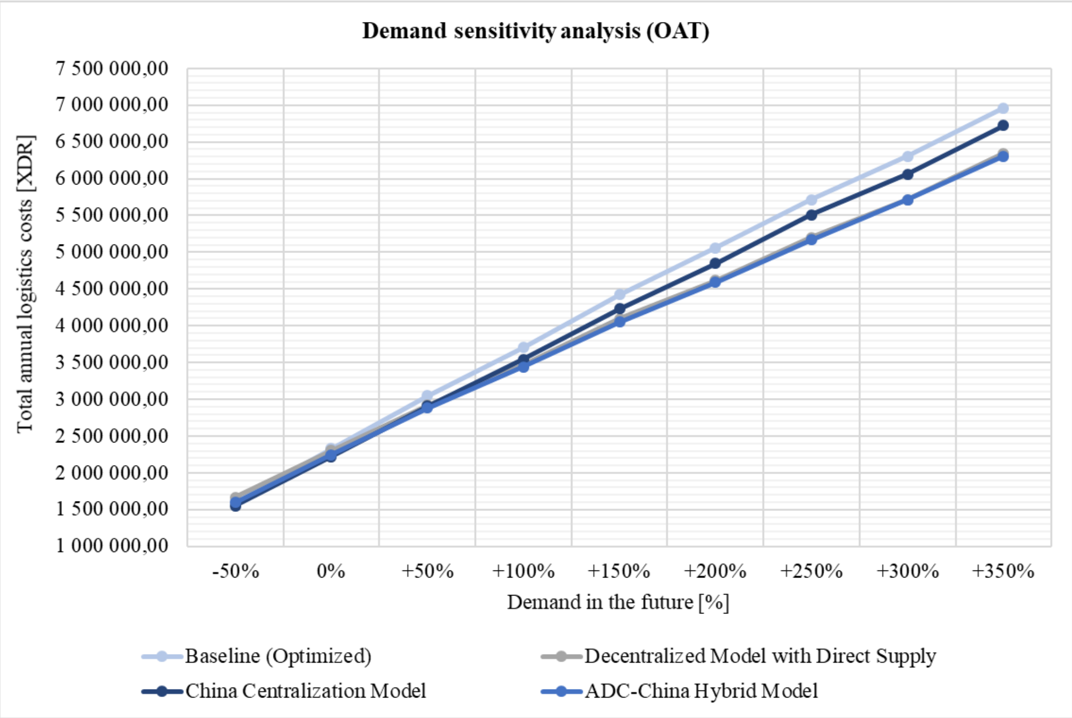
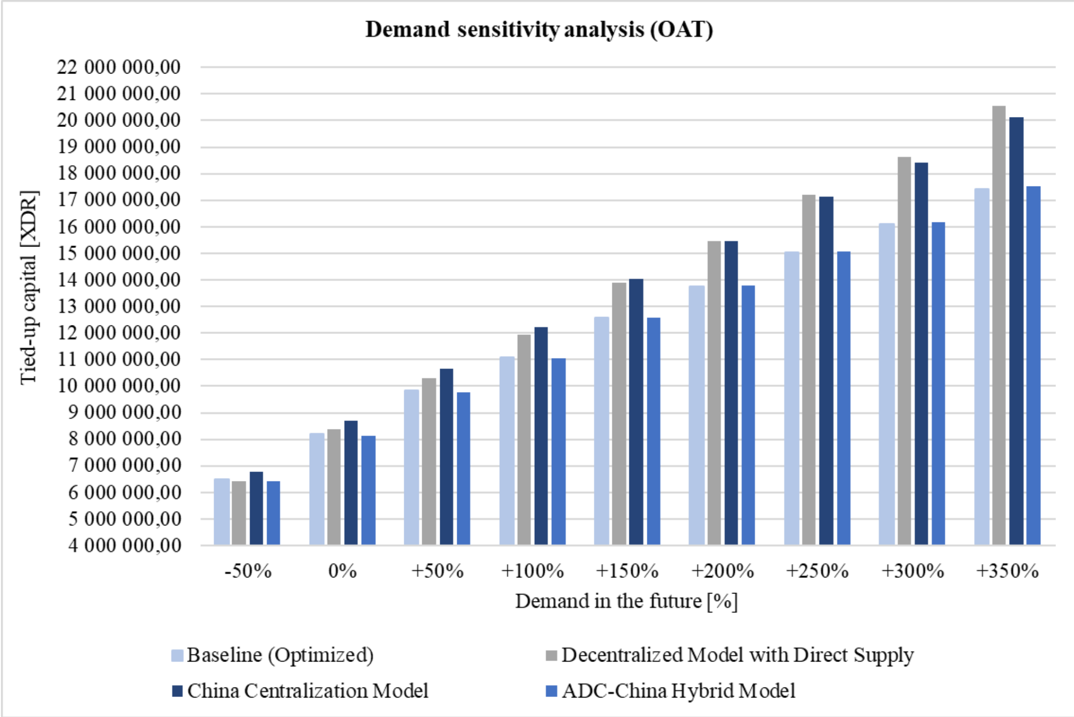



**Table 41. Demand sensitivity analysis in terms of tied-up capital**

| | -50% | 0% | +50% | +150% | +250% | +350% |
|---|---|---|---|---|---|---|
| A) Baseline (Optimized) | 6 497 172,43 | 8 186 019,77 | 9 827 763,90 | 12 594 717,19 | 15 033 299,33 | 17 416 008,36 |
| B) DM with DS | 6 406 353,01 | 8 368 113,72 | 10 310 741,25 | 13 890 552,87 | 17 206 840,21 | 20 562 250,03 |
| C) China Centralization | 6 778 667,54 | 8 704 763,93 | 10 663 867,55 | 14 043 216,54 | 17 140 422,50 | 20 126 733,69 |
| D) ADC-China Hybrid | 6 424 534,46 | 8 116 933,13 | 9 771 543,87 | 12 589 330,29 | 15 080 554,83 | 17 540 912,39 |
| Leading Scenario | "B" | "D" | "D" | "D" | "A" | "A" |



### 9.4.2 Transportation cost sensitivity analysis

The second sensitivity analysis subset to be underwent is transportation cost sensitivity. Table pair 42 and 43 below summarize the results of this analysis, former in the light of logistics costs and the latter in the light of the commitment of capital, when transportation unit costs or in other words freight rates are varied. In the analysis, the sensitivity inspection has been conducted by thinking and changing the freight rates as a rate. The impact of transportation costs on the network is fairly clear on the transportation side, but in warehousing their consideration with modeling means is more challenging. After a long pondering, the cost implications were also decided to tie to the ordering cost parameter (S) used in inventory planning, of which 50% was estimated to be generated by transportation costs. Thus, the sensitivity analysis could be expanded to cover the entire distribution network instead of just being a simple transportation review.

As can be noted from the tables and related graphs depicting the transportation sensitivity analysis, the “China Centralization Model” scenario alternative seem to be the best one to adapt to the changing freight rates in terms of incurring costs, which is due to the minimized transportation needs (as noted before). However, the heavy multi-echelon warehouse structure of the scenario starts to “raise its head” in the light of tied-up capital as the growing freight rates tend to increase the need for stockholding in order to be able to bring the order quantities and hence replenishment volumes to an economic level. In relation to the other scenarios, the tied-up capital is therefore thoroughly the largest in the “China Centralization Model” scenario, thus weakening its overall financial performance as capital efficiency deteriorates remarkably. A similar, but slightly more moderate, trend is observed in the “Baseline (Optimized)” scenario as well. This is due to the fact that, from the viewpoint of material flows and so transportation the scenarios’ distribution structures are rather similar and hence their models behave in the same style (similar slopes in the graphs). However, the current state and related results in terms of the decision variables set the frame for each scenario’s development, which in turn explains the observed differences in the outputs.

Instead the “Decentralized Model with Direct Supply” and “ADC-China Hybrid Model” scenarios, which make more use of transportation in the current state, seem to behave in a contrariwise manner than above. From these, the “Decentralized Model with Direct Supply” scenario alternative where the distribution network is heavily based on transportation due to the direct distribution, is the most prone to cost growth as the freight rates change, which is reflected in the form of a very ascending cost curve. On the other hand, in the scenario there is already quite a lot of stock-bound material in the APA frontlines’ NDCs, so that the change in inventory levels and hence in tied-up capital is not so visible. Thus, the scenario can surprisingly well adapt to the increase of order quantities and consequent stock growth, which are due to the growing freight rates. Similar kind of development is also seen in the “ADC-China Hybrid Model” scenario (similar slopes in the graphs), but since here the initial situation is more favorable due to the advantageous hybrid network structure, this will be able to cope with the changing freight rates better than the aforementioned. As can be noticed, the “ADC-China Hybrid Model” is particularly brilliant in the capital commitment review, being a clear leader. Here, however, it can be found that towards the end the “Decentralized Model with Direct Supply” scenario begins to catch up the situation slightly due to its better adaptability to growing order quantities. This is, though, not enough to destabilize the “balances of power”.

As a wrap up, it can be stated that the “ADC-China Hybrid Model” scenario along with the “Baseline (Optimized)” scenario seem to be the best alternatives in terms of complying with increasing transportation costs (especially at the most realistic 0%→+100% growth level), and therefore being the most robust options for the future. The mutual valuation of these is then a question of preferences between incurred costs and tied-up capital. Of course, the extreme alternatives ergo the “China Centralization Model” and “Decentralized Model with Direct Supply” scenarios do pretty well when looking at the situation only from one perspective (the accumulation of costs or the commitment of capital), but when the other "complementary" view is taken into account, the overall picture in terms of the financial performance becomes significantly weaker and therefore these are not that lucrative options.

**Table 42. Transportation cost sensitivity analysis in terms of total logistics costs**

| | -50% | 0% | +50% | +100% | +150% | +200% |
|---|---|---|---|---|---|---|
| A) Baseline (Optimized) | 2 027 083,33 | 2 327 975,17 | 2 622 947,74 | 2 912 987,96 | 3 198 855,57 | 3 478 590,50 |
| B) DM with DS | 1 967 425,00 | 2 304 379,70 | 2 639 256,50 | 2 968 397,89 | 3 298 327,72 | 3 624 498,10 |
| C) China Centralization | 1 940 049,05 | 2 220 631,58 | 2 496 333,14 | 2 767 971,69 | 3 036 380,87 | 3 302 079,71 |
| D) ADC-China Hybrid | 1 913 457,84 | 2 247 316,39 | 2 576 768,93 | 2 901 347,15 | 3 221 936,82 | 3 536 965,81 |
| Leading Scenario | **"D"** | **"C"** | **"C"** | **"C"** | **"C"** | **"C"** |

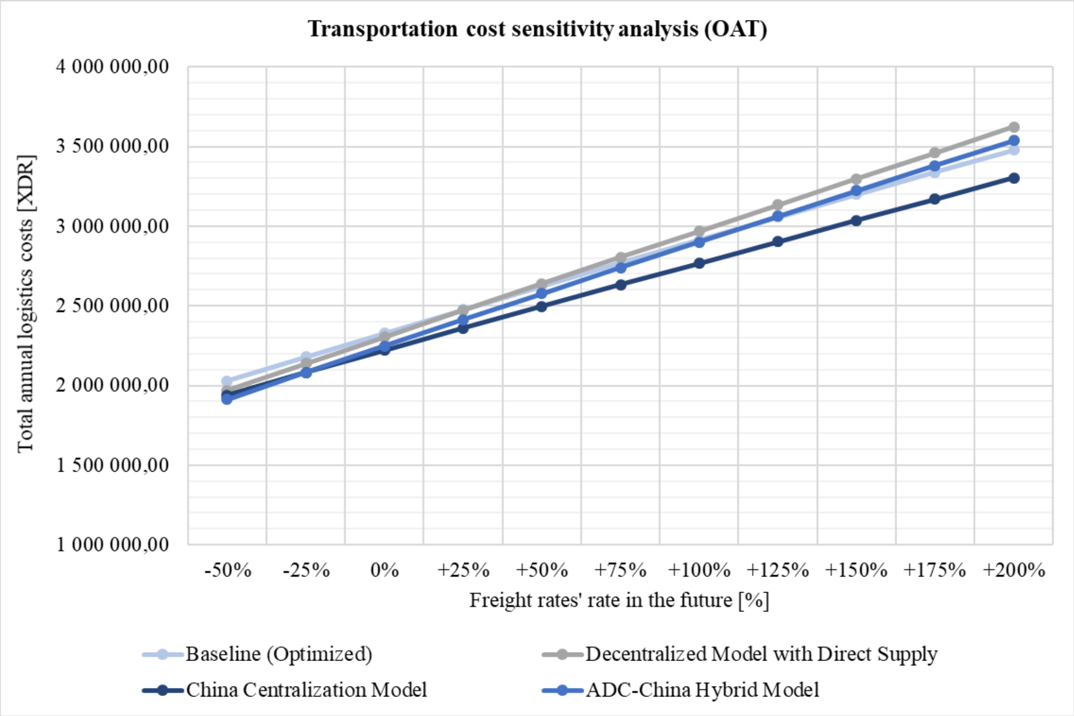
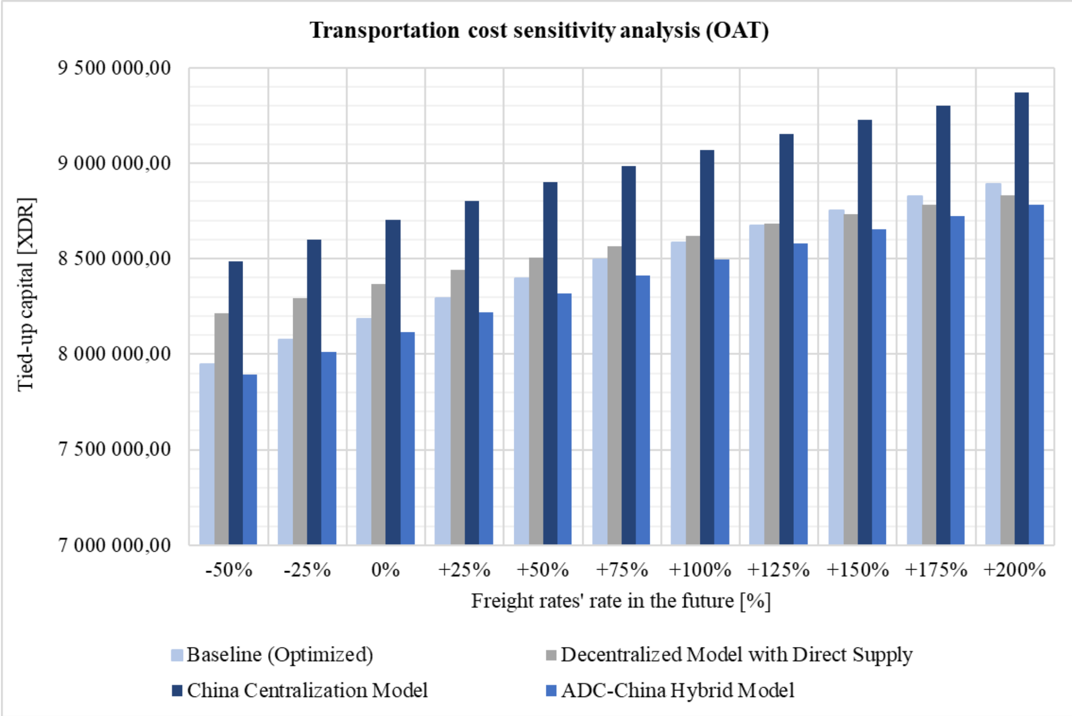



**Table 43. Transportation cost sensitivity analysis in terms of tied-up capital**

| | -50% | 0% | +50% | +100% | +150% | +200% |
|---|---|---|---|---|---|---|
| A) Baseline (Optimized) | 7 947 698,66 | 8 186 019,77 | 8 397 956,32 | 8 586 429,39 | 8 753 284,22 | 8 890 995,14 |
| B) DM with DS | 8 216 749,61 | 8 368 113,72 | 8 506 297,11 | 8 620 251,17 | 8 735 099,03 | 8 832 673,77 |
| C) China Centralization | 8 484 081,77 | 8 704 763,93 | 8 898 645,86 | 9 071 295,26 | 9 226 748,45 | 9 371 041,84 |
| D) ADC-China Hybrid | 7 893 822,82 | 8 116 933,13 | 8 319 226,40 | 8 497 812,45 | 8 654 777,18 | 8 784 806,07 |
| Leading Scenario | **"D"** | **"D"** | **"D"** | **"D"** | **"D"** | **"D"** |



### 9.4.3 Warehousing cost sensitivity analysis

The third and final sensitivity analysis subset to be underwent is warehousing cost sensitivity. Table pair 44 and 45 below summon the results of this analysis, former in the light of logistics costs and the latter in the light of the commitment of capital, when warehousing costs or more precisely holding costs are varied. As above, the sensitivity analysis has also been carried out by thinking and changing the variable inventory holding costs (i) as a rate. When it comes to the impact of holding cost changes, at the network level this has an effect not only on the warehouse operating costs, but also on the order quantities (Q) and hence both stockholding and transportation.

As can be noted from the tables and related graphs depicting the warehousing cost sensitivity analysis, the "ADC-China Hybrid Model" scenario seems to be the best alternative to comply with the changing holding costs in terms of both incurring costs and stock-bounding capital. This is because in this hybrid scenario the network structure is such that delivering to the target markets can be conducted in the most cost-effective manner, since the stockholding locations are such that distances and lead times in the distribution area can be kept moderate while also maintaining rationality in both storing and flow of materials. Hereby in relation to the other options, the scenario can best adapt to a situation where stockholding would start to cost significantly more than the present and therefore the focus of the distribution chain would need to be shifted to a greater extent to transport-led by gradually intensifying replacement frequencies and hence reducing inventories. Almost to the same can match the current network structure, that is the "Baseline (Optimized)" scenario alternative, where similarly a multi-echelon network structure combined with a regional central stock function located favorably in relation to the distribution area enables this shift of focus, thus reducing the storage burden and fighting against rising holding costs. However, in this option the high logistics costs of the current state seem to act as a constraint and as a result of this the cost-effectiveness is slightly lagging behind other scenarios.

Similarly, but conversely the "Decentralized Model with Direct Supply" and "China Centralization Model" scenario alternatives, where both distances and lead times are longer within the network and storage bases much "heavier", will perform weaker in the review. This is because in the scenarios the replenishment processes turn to be more troublesome and hence the storages must act more of safe deposits with high reserves than in the previous scenarios. Thus, downsizing order quantities and shifting to a greater extent to a transport-led operating model will not produce as significant advantages in reducing the stocking burden as in the "lighter" options described above. This is particularly emphasized within the commitment of capital. In the light of the costs these scenarios though seem to cope a somewhat better. This is explained by the fairly moderate cost accumulations achieved in the current state, which are carrying the future. However, in longer reach projections the course would seem to start to turn.

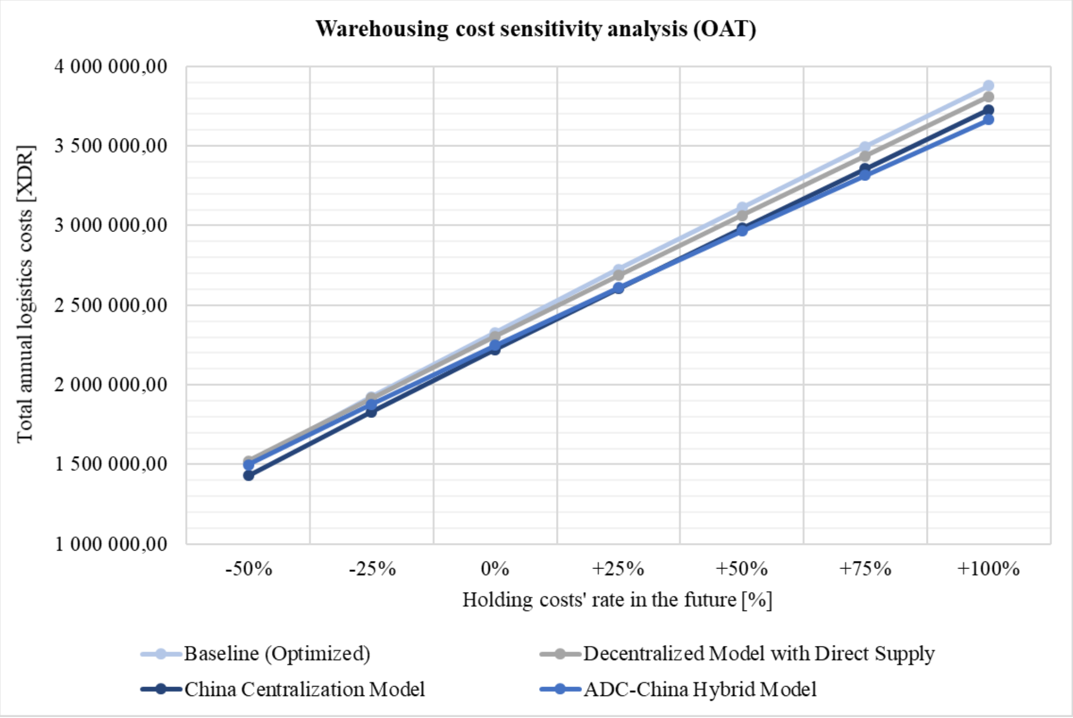
As a conclusion, it can be stated that the "ADC-China Hybrid Model" scenario seem to be the best alternative in terms of complying with increasing warehousing costs (especially at the most realistic 0%→+50% growth level), and thus being again the most robust option for the future. On the other hand, if the slightly higher incurred costs do not hurt, the "Baseline (Optimized)" scenario alternative is also quite functional in this respect. In practice as there were not that radical differences in terms of costs, the superiority must be determined from the viewpoints of capital efficiency and network adaptability.

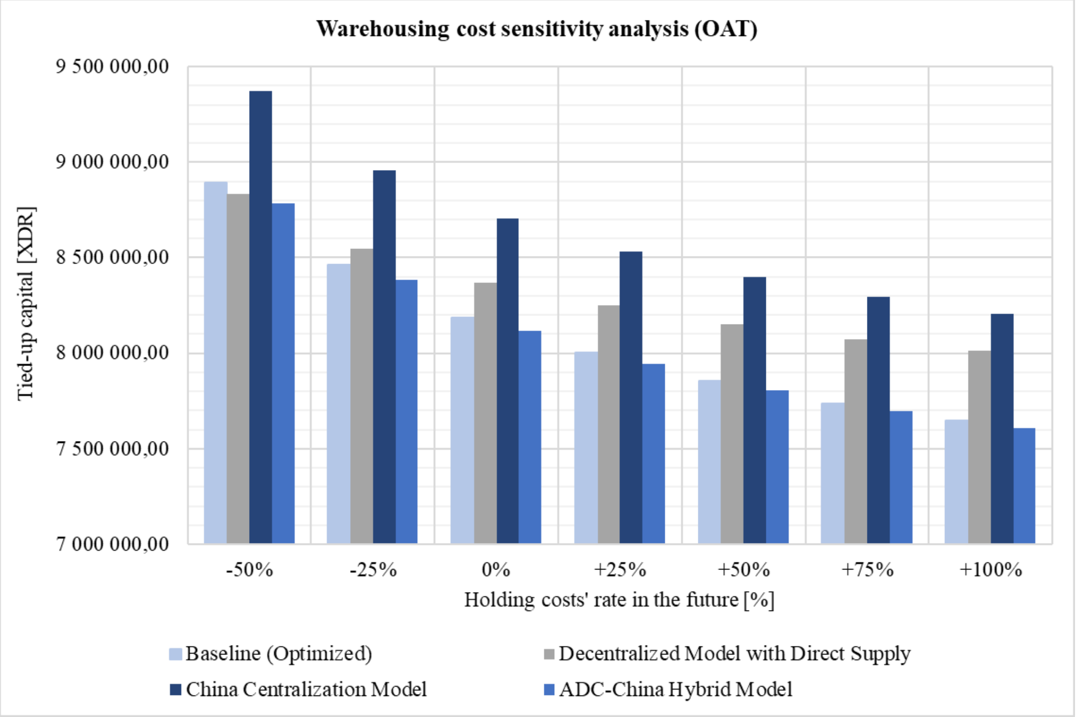
**Table 44. Warehousing cost sensitivity analysis in terms of total logistics costs**

| | -50% | 0% | +50% | +100% |
|---|---|---|---|---|
| A) Baseline (Optimized) | 1 507 342,75 | 2 327 975,17 | 3 112 600,20 | 3 877 620,33 |
| B) DM with DS | 1 522 693,14 | 2 304 379,70 | 3 063 758,31 | 3 809 533,66 |
| C) China Centralization | 1 430 438,55 | 2 220 631,58 | 2 983 059,59 | 3 726 760,24 |
| D) ADC-China Hybrid | 1 497 109,50 | 2 247 316,39 | 2 965 813,12 | 3 665 912,93 |
| Leading Scenario | "C" | "C" | "D" | "D" |

**Table 45. Warehousing cost sensitivity analysis in terms of tied-up capital**

| | -50% | 0% | +50% | +100% |
|---|---|---|---|---|
| A) Baseline (Optimized) | 8 890 995,14 | 8 186 019,77 | 7 853 349,67 | 7 647 899,07 |
| B) DM with DS | 8 832 673,77 | 8 368 113,72 | 8 151 361,16 | 8 015 353,18 |
| C) China Centralization | 9 371 041,84 | 8 704 763,93 | 8 401 019,44 | 8 207 301,72 |
| D) ADC-China Hybrid | 8 784 806,07 | 8 116 933,13 | 7 805 367,13 | 7 610 210,60 |
| Leading Scenario | "D" | "D" | "D" | "D" |



# 10 DISCUSSION AND CONCLUSIONS

As the generated what-if scenarios have now been properly underwent and analyzed, it is time for the final discussion and conclusions. The next chapter compiles and discusses the results of the study, whit an aim to highlight the most favorable alternatives taking into account various decision aspects and based on these compose a good quality development roadmap for the future. After this, the impacts of the presented network design study and its in-depth results and recommendations on the core of the business, that is the maintenance service, are discussed from the viewpoints of both daily maintenance work and end customer satisfaction. At the end of the chapter, the main constraints that have been encountered during this study are brought to the table and based on these a set of additional research topics for possible next steps are provided, through which the study could be complemented, if necessary.

## 10.1 Results compilation and development roadmap composition

The done study was all about global distribution and related network designing with an aim to find the most profitable and operationally efficient way to distribute spare parts in the APA area for the future. To accomplish this, a logistics network design study was conducted, which through many intermediate stages produced a set of scenario alternatives to choose from. The following compiles and discusses the results of the study from various decision-making aspects, that are:

1. *Strategic fit*
2. *Effectiveness and operational efficiency*
3. *System functionality and operational risks involved*
4. *Ease of implementation*
5. *External environment risks*

As a result of this encompassing pondering, one gets informed about all the options as well as the various aspects behind these. Based on this, an informed recommendation for the future direction can finally be produced. All this is also visualized in terms of a generic decision matrix, which is presented in APPENDIX 4.

*1.* When starting to compose a recommendation based on study this nature, the first and often the most meaningful thing to do is to look at the situation from a strategic point of view in order to ensure the strategic fit of the alternatives. As for the what-if scenario development, among the firsts things to be considered when starting to build the scenarios were the case company's vision of *"Right part at the right time to the right place cost-effectively and at the optimized inventory costs"* and strategy *"Winning with Customers"*, on which the what-if scenarios were based and which they strive to respect for their best. Thus, in relation to strategic goals and perspectives, the scenarios are somewhat on the same line as each scenario alternative can achieve the desired service ability and performance goals.

When it comes to competitive advantage and its development, in reference to the competitiveness matrix presented at the beginning of the work (see Figure 3), efforts have been made to move the business conditions more strongly towards the ultimate point of the matrix, the *"Cost and service leader"* section, where the idea is summarily *"providing superior value at less cost"* using logistics leverage opportunities. Like was seen, the what-if scenarios have been quite successful in this. Therefore, the potential for accomplishing a competitive advantage in relation to competitors will be notably improved by the scenarios (in comparison to the current state), be the final choice any of the alternatives presented.

*2.* The second fundamental factor affecting the recommendation composition is of course the effectiveness and operational efficiency of the scenarios, which during the study were analyzed in the light of following key sectors and related figures: *service ability, capital efficiency* and *cost-effectiveness*. Based on studies conducted, it can be stated that with regard to the key figures, the best-performing alternative both now and in the future is the hybrid network alternative, that is the "ADC-China Hybrid Model" scenario. As noted in the previous chapter, the differences between the scenarios are yet, though, quite moderate at the prevailing demand and cost level, and thus in relation to the current state "Baseline (2017)" each alternative can produce significant improvements to the operational efficiency and service ability of the network while also reducing both costs and capital committed. However, when the situation was varied in the form of sensitivity analyses, it became apparent that the "ADC-China Hybrid Model" scenario is the most viable and robust alternative to achieve the best both financial and operational performance in terms of the ROI indicator (see Figure 4). Behind this, the situation was somewhat more varied, but the second-best option was the “Baseline (Optimized)” scenario, which is especially competitive with smaller changes. However, with larger changes, the difference between the leading “ADC-China Hybrid Model” scenario began to become more and more greater. As for the other scenario alternatives, the “Decentralized Model with Direct Supply” scenario and the “China Centralization Model” scenario, these were able to produce comparatively good results in individual areas, but when considering the whole and especially the long-term profitability, these were not as prolific or robust as the aforementioned alternatives, as was seen in the comparisons and analyses of the previous chapter.

3. The third aspect considering which the scenario alternatives are reviewed during this recommendation composition phase is the overall system functionality and operational risks involved. As for this generic functionality and related risks, the most secure and low-risk option from the viewpoints of network operation and day-to-day distribution is, as expected, the optimized version of the current distribution system, that is the “Baseline (Optimized)” scenario. This is mainly because it runs on the basis of an established operational entirety where both the network structure and the operation chains within it are familiar, thus enabling high overall functionality while also reducing the risks associated with the operation. At the same time, the scenario’s multi-echelon network structure with central logistics is in itself a conservative and secure option for its concentrated regional stockholding and centralized distribution. This conservativity brings secure for the future as was seen for instance in the results of the sensitivity analyses when key design inputs were varied. Nevertheless, this distribution network is relatively expensive to both maintain and operate, and it is not possible to achieve the same level of efficiency with this as in other scenarios, because of its longer intermediated distribution chain where the flow of materials is not adequately optimized due to the scope and fragmentation of the distribution area. In order to achieve the best capital efficiency and cost-effectiveness with the desired service ability, a more radical option should be chosen (especially in the longer run).

From the more radical options the most functionally viable alternative in terms of efficiency and effectiveness in relation to the estimated risks is the “ADC-China Hybrid Model” scenario, which alike relies heavily on the current state operation and its network structure. In the scenario, the distribution chain has, thought, been condensed by differentiating material flows and carrying out their distribution to the target markets from designated regional distribution centers (the China material flow comes directly from the CDC, and the material flow coming from Europe is conducted through the ADC as currently). Hence, the materials distribution can be implemented more efficiently, both in terms of costs and capital, while also eliminating unnecessary doing and waste from the network. Despite these changes, the system along with its hybrid network structure is designed to be functionally stable and secure, which when well implemented, will make it possible to achieve very good results with the least risks. This was indicated in the done sensitivity analysis, where the scenario outdid other alternatives in all classes.

As for the two other options, the “Decentralized Model with Direct Supply” scenario and the “China Centralization Model” scenario, these are instead likely to more or less increase the risks associated with the network and distribution activities, as major structural and hence operational changes will be needed in both alternatives. At the same time, the implementation of the distribution chain will start to focus heavily on one single area (in the former on transits and in the latter on stockholding) what for potential for failure and hence uncertainty tend to increase in comparison to the more stable and secure options outlined above. This can especially be expected to be present in the “Decentralized Model with Direct Supply” scenario. Thus, this system functionality and operational risks involved aspect would again favor the “Baseline (Optimized)” and “ADC-China Hybrid Model” alternatives.

*4.* The fourth aspect to be considered during this recommendation composition phase is the ease of implementation. When it comes to implementation of both the network structure and related operational elements, the optimized version of the current state, that is the “Baseline (Optimized)” scenario, is as expected the easiest to put in action. Here in summary the material flows will be rationalized and remodeled, while also refining and optimizing both inventories and transportations in the network from the viewpoint of the entire distribution chain. Despite these rather fundamental changes, the scenario maintains the existing network structure, which means that initialization will not require any major structural changes, as opposed to other scenarios, thus facilitating the implementation of the alternative. After this, the second most preferable option regarding implementation is the hybrid network structure ergo the "ADC-China Hybrid Model" scenario. This is simply because in this alternative virtually all that is needed is already in the prevailing network and hence the only additional effort needed in comparison to the above-mentioned is the separation of the material flows and the launch of direct distribution from China.

As for the other scenarios discussed, in these conversely the distribution systems and related structures will already need to be changed to a greater degree, such as in the "China Centralization Model" scenario transfer of the regional central warehouse from Singapore to China in the form of a bonded regional stock, and in the "Decentralized Model with Direct Supply" scenario the shutdown of the ADC and launch of direct distribution from both the EDC and the CDC, in order to get the entirety up and running. Hence, these would require more or less additional efforts in addition to the "basic development measures" mentioned above. As a wrap up, it can be stated that from the point of view of implementation it would be best to stay in the first two ergo the "Baseline (Optimized)" scenario and the "ADC-China Hybrid Model" scenario. Of course, the choice should not be directly done in this respect, but to take the issue again more as a guiding factor.

*5.* The fifth and final fundamental factor affecting the composition of the recommendation is external effects in the form of an operational environment. With respect to this, the scenarios are, though, rather similar apart from central logistics. So, the review will focus on this. As can be seen from the study, centralized logistics and the central stock function are very important for the global distribution system to be able to operate cost-effectively and at the same time minimize stock-bound capital. In the scenarios, the central stock function(s) were carried out in two ways, in a fully centralized manner as in both the "Baseline (Optimized)" scenario and in the "China Centralization Model" scenario and in two parts as in the "ADC-China Hybrid Model" scenario. As for the location, these were placed alternately in Singapore, in China and in the hybrid network for both.

When looking at the selection from the viewpoint of operational environment, in this respect, there are no significant differences in the long-term prospect, which would directly govern the choice. Although the globally integrated and business-friendly Singapore is still one step ahead the ascending China from the viewpoints of both foreign trade and logistics (as can be seen from the data set in Table 46 below), China is in strong momentum drawing this distinction. This is because the country is constantly opening up to foreign trade, while its regulation is declining and both political climate and the financial system are stabilizing. At the same time, the congested logistics infrastructure (especially in larger ports and airports), that has posed challenges in recent years, is expected to develop and grow over the next few years led by the government's investments in infrastructure. In the near future, it is hence possible to believe that the interface with respect to Singapore as a both logistic and business center is getting tapered, especially given China's significantly lower price level. Consequently, if in China will be operated through trusted 3PL service providers who are familiar with the country's practices and regulations as well as be seizing the trade incentive opportunities (as done in the study), there are no major obstacles to a partial or even a full-scale transfer of regional distribution operations to this end in the long run. However, currently Singapore is still a more attractive alternative to distribution, especially given the recent geopolitical tensions and the US-China trade war which according to current information are, though, not expected to spread more widely.

**Table 46. Operational environment comparison between China and Singapore in 2018**

| **Operational environment comparison** | | **China** | | **Singapore** | |
|---|---|---|---|---|---|
| *Performance indices* | (*) Ease of doing business index (global ranking) | **2016** | **2018** | **2016** | **2018** |
| | | ( 78/190 ) | 46/190 | ( 2/190 ) | 2/190 |
| | (**) Logistics performance index (LPI) (global ranking) | **2016** | **2018** | **2016** | **2018** |
| | | ( 27/160 ) | 26/160 | ( 5/160 ) | 7/160 |
| *Country risk characteristics* | Political risks | Moderate (3/5) | | Very Low (1/5) | |
| | Economic risks | Low (2/5) | | Low (2/5) | |
| | Financial system risks | Moderate (3/5) | | Very Low (1/5) | |

*(*) Within the index, economies are ranked on their ease of doing business in terms of the operational environment. The index consists of 10 both qualitative and quantitative measures and it allows for comparisons across 190 countries.*

*(**) Within the index, countries are ranked on their performance on trade logistics in order to help build the profiles of countries' logistics friendliness. The index consists of 6 merged measures and it allows for comparisons across 160 countries.*

(A.M. Best 2018; The World Bank 2018a; The World Bank 2018b)

As can be drawn from the above discussion, a clear choice for the direction of future development would be a transition to the “ADC-China Hybrid Model” scenario network structure, which enables in a stable and secure manner the most efficient yet effective spare parts distribution in the future. Since the distribution network is, though, a constantly running entity and the difference between the scenario and the current state “Baseline (2017)” is both operationally and on the network level relatively large, it would be better to proceed in small incremental steps. This is also recommended by the operational environment as well as the results of the performed scenario comparison and analysis, where the optimized version of the current state i.e. the “Baseline (Optimized)” scenario could achieve relatively competitive results. Thus, from the point of view of change management, the most sensible long run development roadmap would be: *Baseline (2017) - Baseline (Optimized) - ADC-China Hybrid Model*, as illustrated in Figure 31 below.

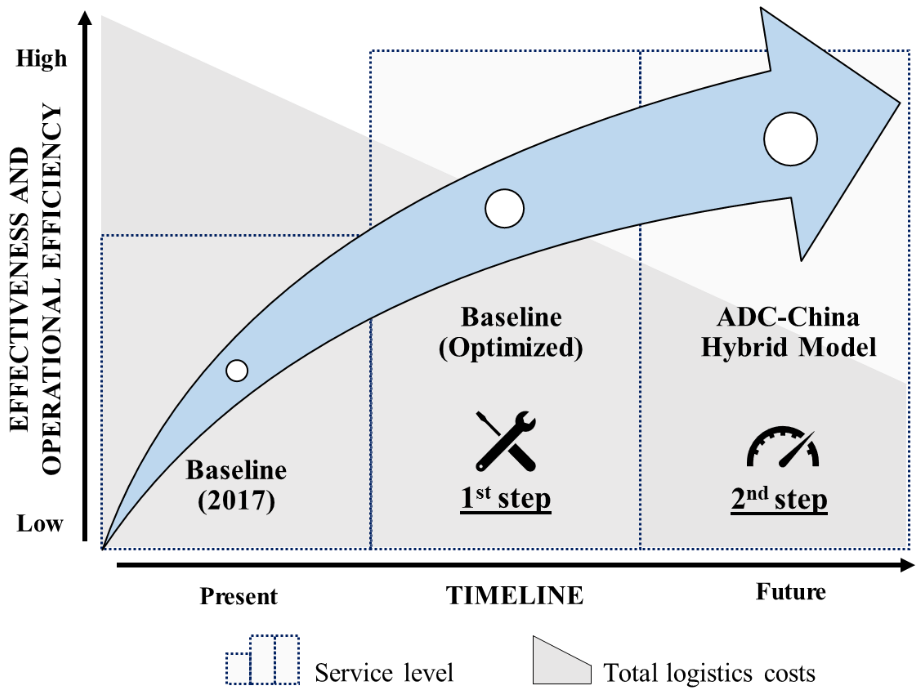



**Figure 31. Illustration of the proposed development roadmap to a more effective and operationally efficient spare parts distribution for the future**

Accordingly, the idea would be to start the development process in the near future by initially bringing the current state up-to-date through the optimized operating model, which in itself can bring a significant step forward in comparison to the “Baseline (2017)”. Hence, the former step of development is trying to restore the distribution network and related operations on the right track while increasing the effectiveness and operational efficiency of the system. Subsequently, as the distribution network and its operations along with the APA area’s sales activity and China's operational environment are all mature enough, the next longer-term step would be to move to the “ADC-China Hybrid Model” scenario structure. This would be done by gradually separating the EDC and CDC material flows from each other and starting the centralized distribution from China (CDC) directly to the APA area frontlines’ NDCs. At the same time, the ADC would be cleared piecemeal from the CDC items. When the time is right, the network can be fully embedded in the new two-channel distribution model of the scenario. In this way, the latter step of development seeks better financial performance by increasing the overall cost-effectiveness through a structural shift and by reducing the network committed capital. As can be seen from the figure, this all will be done without sacrificing the service ability of the system.

When it comes to the network coordination allocation and status information used in this, management and coordination of the entirety should initially be centrally deployed from an upper level to be able to effectively and, above all, successfully implement the addressed changes to the distribution network and its activities. Over time, once the new system is up and running and the operations of the APA area frontlines start to stabilize, it would be desirable to move the driving force gradually closer to the core of the action, that is on the country level, and hence to a more pull-based scheme. Here it is, though, important to keep in mind and stick to the created network-wide operating model and the established policies so that the operations do not start to meander in the present way. It is also essential to maintain a visibility and open exchange of information between the parties in the network.

## 10.2 Impacts of the recommendation on maintenance service

As the recommendation for the future has now been reached, it is worthwhile to also consider the impacts of this on the core service business, that is the maintenance service. The aspects that are to be reviewed in this more far-reaching deliberation are the effects of the recommendation on daily maintenance work and its influence on the end customer satisfaction. This section was included in the chapter to highlight the customer service aspect, which along with financial performance and competitive advantage should be among the higher-level interests of every logistics related development work.

The biggest advantage of the recommendation in terms of maintenance service is the shift of the distribution network's focus closer to the consumption, that is to the frontlines' NDCs, and the followed rise of inventory service levels, which together allow for maintenance to work without unnecessary material related delays and hence received service jobs can be completed faster. Since the average service level in the scenarios in question has been raised to ~93%, this means that with the same probability any desired stock item will be found on hand in the NDC. In addition to this, service levels have also been graduated, which ensures that the most important items can be obtained with up to 98% certainty from NDCs, which is a significant improvement to the current ~70% service level. This in turn means that, as the item is readily available at the country level, it can be delivered on the same day or at its best within a couple of hours to the worksite via express parcel. Therefore, the number of on-time and in-full (OTIF) deliveries can likewise be dramatically increased and speeded up, which in general is an important success factor especially in this time-sensitive sector of service business. And all this has been achieved with a smaller resource amount than before.

For maintenance personnel, the aforesaid development measures are reflected as the better availability of materials and hence as an opportunity for both more efficient and effective working. These will respectively appear in the form of increased first-time fix rates, faster job order completion as well as a general reduction of hurry and need for unnecessary multitasking. For the end customers, the above description is analogously shown as a faster response and uninterrupted service chains. At the same time, the value experienced by customers will also be improved, which is further seen as a growing customer satisfaction and perhaps as additional sales. As the proposed development roadmap will perform from a resource perspective much more efficiently than the current system, this also allows for a better allocation of resources as well as applying the remaining resource surplus (or even part of this) to the further development of customer interface functions, which would yet enhance the value creation and satisfaction experienced by customers. Thus, the case company's strategy *"Winning with Customers"* could be more comprehensively implemented in service production of the APA area.

## 10.3 Constraints of the study and suggestions on next steps

Although the study found answers to the presented research questions and reached the set objectives, there were a few constraints that prevented the research from being done in the same way and as widely as it was originally desired. Consequently, the study had to be performed under these circumstances and hence either adapt the work or leave something outside of the scope. Next the main constraints will be covered and described how these influenced the outlined study. At the same time, potential additional research topics for next steps will also be highlighted, which would allow the study to be complemented.

The first constraint of the study was the shortcomings in the item level criticality data, which eventually meant that the work could not take a better stand on the item-specific distribution. Because of this, in the study had to be assumed that all items would be as critical to the operation and maintenance of the end-user's devices, and hence each item should be equally available. While this is not, in the end, a bad thing in terms of network design and operations planning, in reality some of the items are, though, more critical than others, which should also be taken into account in the end design to reach the best achievable operational efficiency. If more accurate and above all more reliable criticality data will be available in the future, it would be advisable to carry out an item level criticality analysis and classification, and on this basis to specify the distribution planning on the item level. In accordance with Abele et al. (2008, pp. 291-292), the idea could for example be to position less critical and expensive/slow-moving spare parts backward in the distribution chain by concentrating these regionally in a central stock function (RDC) and delivering the items directly from there to the worksites as needed; while more critical spare parts would remain in the scope of decentralized stockholding, that is in the frontlines' NDCs, as currently. The benefit of this would be, that it would allow a further reduction in the storage burden of the distribution network, which in turn would yet improve both the capital efficiency and the overall cost-effectiveness.

For the second constraint of the study could be raised the current prevailing freight rates and their inconsistency and unbalance at the regional level, what for cross-docking in regional distribution did not appear to have the desired benefits in the modeling. Hence, in the study cross-docking had to be restricted only for the long-distance transportation of the "Decentralized System with Direct Supply" scenario. However, if in the future the freight rates can be negotiated more favorable, then this cross-docking arrangement, especially with regard to the KEA area, could also be harnessed in the scenarios of the proposed development roadmap. Thus, from a theoretical point of view some extra degree of the economies of scale could be achieved as the average delivery volumes are made larger through pooling. This would correspondingly lead to a further reduction in transportation costs while also improving the operational efficiency of the network.

The third constraint to be considered here is the very holistic aspect chosen for both materials management and modeling of replenishments in the scenarios, which is, though, not necessarily the most optimal option from the viewpoint of implementation. Therefore, when the results of the study are implemented, it would be advisable to consider the situation on a country-by-country basis and try to find the most appropriate replacement frequencies (in the models both daily and weekly depending on the transportation need) and the ratios between the modal choices (in the models "80/20" according to the Pareto principle). The same goes also for inventory planning and related parameters throughout the distribution network. When this is done, it is possible to achieve the best possible cost-benefit ratio from each line of the distribution system taking into account the prevailing capabilities and the individual situation in each country.

For the fourth no longer a constraint, but rather a potential additional research topic could be pointed out the global focus of the study, which in turn meant that the local side of distribution did not understandably get much attention in the review. Although this is a matter of project scoping which had to be made to keep the study within the boundaries of an academic work, the local distribution is very meaningful with regard to the entire distribution chain. This is due to the fact that, after all, the most important thing regarding both maintenance service and customer value creation is to get the spare parts delivered at the desired time to the desired place in full (OTIF), which is ultimately among the responsibilities of local distribution. Consequently, in order to be able to fully exploit the results presented in this work, it would be more than desirable to carry out a similar kind of logistic network study also locally in each target country. At the same time, one also gets assurance that the entire distribution chain with all of its parts will work as wanted.

The fifth and final constraint to be addressed here are the assumptions and estimates made during the study, both in inputs and in operations (see Table 11), which should be kept in mind when interpreting the study and its results. This is because, even though the study has been conducted to as far as possible describe reality, models are always just models that present the situation in the best possible manner in the light of the information entered and the rules set. It is likewise important to accentuate that the results are based on the best available data and estimates at the time and may change in the future.

# 11 SUMMARY

The study outlined was all about spare parts distribution in the APA area and acts as a preliminary account for the development of KONE GSS' distribution network and operations management, as the case company is aspiring to fundamentally raise its performance and competitiveness in this ascending market area. The main research problem of this study was thus the case company's higher-level network structure and distribution operations in the APA area whereby the company have had issues. The objective was to analyze the current state of distribution within the area and based on this, through network design means, strive to draw the most profitable and operationally efficient way to distribute spare parts in the area for the future taking into account the various characteristics and requirements of the business.

The research was conducted as a theory-based problem-solving and modeling study. The study started with a literature review, where the basic building blocks and design premises of a global distribution network as well as the specific characteristics and requirements of spare parts industry were introduced. In addition to this, guidelines for carrying out a network design project along with required data needs and advises to data processing were covered. After this, the theory base combined with a large data set collected from the case company's various data sources was used to build an Excel-based modeling tool, through which the empirical part was conducted. As for the functional principle of the tool, it was designed to rely on optimization combined with comparative scenario calculating. This was then capitalized to model and test different scenario alternatives drawn from literature findings.

The empirical part of the study started with a current state analysis, where the status quo was described, modeled and analyzed, and based of this the prevailing inefficiencies and unsatisfactory elements were outlined. After understanding the current state of distribution, a vast variety of improvement suggestions could be generated. These as well as the existing network structure were then taken as a starting point to what-if scenario development. In the end, four unique network alternatives were built, which were then delineated, modeled and the results of these compared and analyzed thoroughly. Based on this what-if scenario analysis, various conclusions and recommendations for the future could then be derived.

As for the conclusions of the study, the work offered recommendations regarding both the network structure and distribution operations, based on which the case company could make its distribution and supply chain planning more efficient and above all more customer oriented. Based on the done work, a two-step development roadmap for the future was introduced, which would provide better operational and financial performance, and enable achievement of greater competitive advantage. Here the first step would be to start the development process by bringing the current state up-to-date through an optimized operating model, the “Baseline (Optimized)” scenario, which in itself can provide notable improvements over the current state of distribution. In this way many of the drawn fundamental improvements in terms of both the entire distribution chain and its sub functions of warehousing and transportations, can be implemented right a way to the existing structure thus achieving already significant results regarding capital efficiency, cost-effectiveness and service ability in the nearest future. As the time is right, the second step of this roadmap would be a move to a new, more straightforward “ADC-China Hybrid Model” network relying on the prevailing system with a little twist. This in turn can raise the overall performance to a whole new level through the rationalization of material flows and changes in the warehouse network. In addition to these, the distribution operations will be further developed which completes the change for a better future.

As part of the conclusions, the effects of the study on maintenance service were also discussed. Here the main advantage was found to be the radically better availability of materials closer to the consumption, which in turn enables for instance increased first-time fix rates, faster job order completion as well as reduction of hurry and need for unnecessary multitasking. For the end customers, these will be shown as a faster response and uninterrupted service chains, which ultimately reflects in the form of a better value creation for customers and hence greater customer satisfaction. The proposed development roadmap also enables performing much more efficiently from a resource perspective, which will allow for a better allocation of resources and perhaps applying the remaining surplus to further development of the customer interface.

As for the big picture, the study and its results are necessary to the case company for future development. In addition, this brought new ideas and perspectives to the research community as well. Hence it could be stated that the study is very meaningful from several points of view.

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## APPENDIX 1: Variables of inventory planning and management

Below are listed the most common variables of inventory planning and management (used in the network design study) according to the lecture slides of Lappeenranta University of Technology's course CS20A0000 Toimitusketjut ja logistiikka, academic year 2014-2015.

| | | |
|---|---|---|
| $D$ | Demand for the product [pcs/yr.], [X Curr/yr.]<br>[pcs/m.], [X Curr/m.] | |
| $c$ | Cost per unit i.e. Price [X Curr/pc] | |
| $S$ | Ordering cost [X Curr/order] | |
| $i$ | Annual inventory holding cost as a fraction of unit cost [%] | |
| $L$ | Replenishment length i.e. Lead time [d.], [m.] | |
| $EOQ$ | Economic order quantity [pcs] | |
| $Q$ | Order quantity [pcs] | |
| $ROP$ | Reorder point [pcs] | ($ROP = B$) |
| $n$ | Orders during year i.e. Annual ordering frequency [orders] | |
| $M$ | Average demand during replenishment period (L) [pcs] | |
| $I$ | Average inventory i.e. Onhand [pcs], [X Curr] | |
| $CS$ | Cycle stock [pcs], [X Curr] | |
| $SS$ | Safety stock [pcs], [X Curr] | |
| $SLc$ | Service Level per cycle [%] i.e. Facing fill rate | |
| $P(s)$ | Probability of shortages per cycle [%] | ($P(s) = 1 - SLc$) |
| $Z$ | Normal distribution's Z score with probability $SLc$ [-] | |
| $CV$ | Coefficient of variation [-] | |
| $STDEVdm$ | Standard deviation of demand (of the product) per month [pcs] | |
| $AVEd$m | Average demand (of the product) per month [pcs] | |
| $v$ | Inventory turnover [times a year] | |
| $MOS$ | Months of supply [m.] | |

**APPENDIX 2: Equations of inventory planning and management**

Below are listed the most important equations of inventory planning and management (used in the network design study) according to the lecture slides of Lappeenranta University of Technology's courses CS20A0000 Toimitusketjut ja logistiikka, academic year 2014-2015 and CS20A0101 Tuotannon- ja materiaalinohjaus, academic year 2014-2015.

$$EOQ = Q = \sqrt{\frac{2DS}{ic}} \tag{1}$$

$$ROP = M + SS = DL + SS \tag{2}$$

$$n = \frac{D}{Q} \tag{3}$$

$$M = DL \tag{4}$$

$$I = CS + SS = \frac{Q}{2} + SS \tag{5}$$

$$CS = \frac{Q}{2} \tag{6}$$

$$SS = Z \times STDEVd \times \sqrt{L} \quad \textit{, when } CV \leq 0{,}75 \textit{ i.e. continuous demand} \tag{7.1}$$

- $SS = NORMSINV(SLc) \times STDEVd \times \sqrt{L}$ (Office 365 - Excel)

$$SS = ROP - M = B - M \quad \textit{, when } CV > 0{,}75 \textit{ i.e. discrete demand} \tag{7.2}$$

- $SS = POISINV(SLc; M) - M$ (Office 365 - Excel)

$$CV = \frac{STDEVdm}{AVEdm} \tag{8}$$

$$v = \frac{D}{I} = \frac{D}{Q/2 + SS} \tag{9}$$

$$MOS = \frac{I}{D/12} = \frac{Q/2 + SS}{D/12} \tag{10}$$

# APPENDIX 3: Collation of the replenishment lead times in APA area distribution, KONE GSS

## 1. Local Sourcing (Local items)

| Source | Average Supplier Lead Time [calendar days] |
|---|---|
| *Local External Vendors* | 21 |

## 2. Global Distribution (VL06O items)

### 2.1 Line-haul Transportations

| Source Loc. | | | Receiving Loc. | | | Air Freight S7 Lead Time [calendar days] | Sea Freight S3 Lead Time [calendar days] | Express Parcel S1 Lead Time [calendar days] |
|---|---|---|---|---|---|---|---|---|
| *Germany* | **KNED** | **EDC** | *Singapore* | **KNES** | **ADC** | **10** | **48** | **4** |
| | | | *China* | **KNEG** | **CDC** | **11** | **50** | **5** |
| | | | *Australia* | **203** | **KEA** | **11** | **67** | **5** |
| *China* | **KNEG** | **CDC** | *Singapore* | **KNES** | **ADC** | **9** | **32** | **4** |
| | | | *Germany* | **KNED** | **EDC** | **12** | **55** | **5** |
| | | | *Australia* | **203** | **KEA** | **11** | **42** | **5** |

### 2.2 Delivery Transportations

| Source Loc. | | | Receiving Loc. | | | Air Freight S3 Lead Time [calendar days] | Sea Freight S9 Lead Time [calendar days] | Express Parcel S1 Lead Time [calendar days] |
|---|---|---|---|---|---|---|---|---|
| *Germany* | **KNED** | **EDC** | *Australia* | **KEP** | **203** | **11** | **67** | **5** |
| | | | *New Zealand* | **KEP-0001** | **202** | **9** | **73** | **5** |
| | | | *Thailand* | **TLI** | **230** | **11** | **51** | **4** |
| | | | *Malaysia* | **MAL** | **238** | **9** | **51** | **4** |
| | | | *Philippines* | **KPE** | **239** | **12** | **62** | **4** |
| | | | *Indonesia* | **KIE** | **244** | **12** | **57** | **4** |
| | | | *Taiwan* | **KET** | **246** | **11** | **57** | **4** |
| | | | *Vietnam* | **KVI** | **252** | **11** | **58** | **4** |
| | | | *India* | **KEI** | **282** | **11** | **46** | **4** |
| | | | *Hong Kong* | **HKG** | **HKG1** | **9** | **53** | **4** |
| | | | *Singapore* | **SIN** | **SIN** | **10** | **48** | **4** |
| *China* | **KNEG** | **CDC** | *Australia* | **KEP** | **203** | **11** | **42** | **5** |
| | | | *New Zealand* | **KEP-0001** | **202** | **9** | **45** | **5** |
| | | | *Thailand* | **TLI** | **230** | **10** | **25** | **4** |
| | | | *Malaysia* | **MAL** | **238** | **9** | **31** | **4** |
| | | | *Philippines* | **KPE** | **239** | **12** | **25** | **4** |
| | | | *Indonesia* | **KIE** | **244** | **12** | **33** | **4** |
| | | | *Taiwan* | **KET** | **246** | **10** | **24** | **4** |
| | | | *Vietnam* | **KVI** | **252** | **11** | **28** | **4** |
| | | | *India* | **KEI** | **282** | **11** | **36** | **5** |
| | | | *Hong Kong* | **HKG** | **HKG1** | **8** | **28** | **4** |
| | | | *Singapore* | **SIN** | **SIN** | **9** | **32** | **4** |
| *Singapore* | **KNES** | **ADC** | *Australia* | **KEP** | **203** | **11** | **36** | **3** |
| | | | *New Zealand* | **KEP-0001** | **202** | **9** | **42** | **4** |
| | | | *Thailand* | **TLI** | **230** | **10** | **21** | **3** |
| | | | *Malaysia* | **MAL** | **238** | **8** | **21** | **3** |
| | | | *Philippines* | **KPE** | **239** | **12** | **32** | **3** |
| | | | *Indonesia* | **KIE** | **244** | **11** | **27** | **3** |
| | | | *Taiwan* | **KET** | **246** | **11** | **27** | **3** |
| | | | *Vietnam* | **KVI** | **252** | **10** | **28** | **3** |
| | | | *India* | **KEI** | **282** | **10** | **22** | **3** |
| | | | *Hong Kong* | **HKG** | **HKG1** | **8** | **23** | **3** |
| | | | *Singapore* | **SIN** | **SIN** | **-** | **-** | **2** |
| *Australia* | **203** | **KEA** | *New Zealand* | **KEP-0001** | **202** | **7** | N/A | **3** |

**APPENDIX 4: Visualization of the development roadmap composition using a decision matrix**

| *Aspects considered* | 1. Strategic fit | 2. Effectiveness and operational efficiency | | 3. System functionality and operational risks involved | 4. Ease of implementation | 5. External environment risks | Overall score |
|---|---|---|---|---|---|---|---|
| | | *Now* | *In the future* | | | | |
| **Weight** | **5** | **4** | | **3** | **2** | **1** | **( 76 )** |
| A) Baseline (Optimized) | 4 | 3 | 3 | 4 | 3 | 4 | 66 |
| B) Decentralized Model with Direct Supply | 4 | 3 | 2 | 1 | 1 | 2 | 47 |
| C) China Centralization Model | 4 | 3 | 2 | 3 | 1 | 3 | 54 |
| D) ADC-China Hybrid Model | 4 | 4 | 4 | 4 | 2 | 3 | 71 |

The decision matrix works as follows:

- In the matrix, there are five main aspects to be considered, which all have different relative importance for the decision. In accordance with this, the aspects are given their own relative weight in the matrix from 1 to 5.
- In each aspect there are five identified options in terms of meeting the requirement called for here. Depending on how well the scenario meets the requirement, it gets points as follows:
  - *Does not meet the requirement* *0*
  - *Meets the requirement somewhat* *1*
  - *Meets the requirement in a mediocre manner* *2*
  - *Meets the requirement well* *3*
  - *Meets the requirement very well* *4*
- When each aspect is covered, and the points set, then the scores are added up by taking into account the relative weight. In this way, an overall score will be given to each scenario. The greatness of the score will then give an indication of the goodness of the alternative in the light of the aspects considered.

(MindTools 2018)