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Long-term needs for logistics capacity in the pharmaceutical industry

Master's Thesis

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Alkusanat

Tämä diplomityö lienee tähänastisen akateemisen elämäni päätepiste. Voi se toki olla vasta välietappikin, mutta joka tapauksessa selkeä virstanpylväs, jonka avulla uskon osoittaneeni ammatillisen ja akateemisen kypsyyteni tuotantotalouden alalla. Vaikka diplomityö on itsenäinen akateeminen lopputyö, vaatii sen tekeminen ja menestyksekäs valmistuminen myös ulkopuolista tukea. Arvokkaita ovat työn ohjaajan ja valvojan lisäksi myös sukulaiset ja ystävät, joiden tukeen ja apuun voi luottaa.

Suurimmat kiitokset ansaitsevat äitini Merja Savola sekä isovanhempani Anja ja Antti Savola, jotka ovat tukeneet ja auttanet minua koko koulu-urani ajan, aina reppuaan pienemmästä ala-astelaisesta vastavalmistuneeksi diplomi-insinööriksi asti. Te olette aina antaneet täyden tukenne sekä luottaneet ja uskoneet minuun. Ilman teitä en olisi voinut elää ja opiskella vailla suurempia huolia. Tieto siitä, että apu on aina lähellä, on aina lämmittänyt sydäntäni.

Äitini lisäksi kiitän isääni Ari Borgia siitä esimerkistä, jota noudattaen olen uskaltanut lähteä kaukaisiinkin kohteisiin vailla tarkkaa suunnitelmaa. Ilman tätä esimerkkiä en nyt istuisi syksyisessä Zürichissä kirjoittamassa näitä sanoja.

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Lopuksi kiitän sukulaisiani ja ystäviäni, joiden kanssa saatoin keskustella diplomityöni etenemisestä. Ilman varoventtiiliä tiiviskin kattila paukahtaa, ennemmin tai myöhemmin.

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Tässä työssä tutkittiin, millä tavalla suuri lääkealan yritys voi parantaa ennusteitaan pitkän aikavälin varastotilan tarpeelle. Strategisen suunnittelun tukemiseksi yritys halusi kehittää ennustetyökalun, jolla yrityksen globaali varastokapasiteetin tarve voidaan ennustaa jopa kymmenen vuoden päähän. Ennustetyökalun ja –prosessin luominen olivat tämän diplomityön emoprojektin päämäärä. Tämä diplomityö tutki ja arvioi, mitä vaatimuksia pitkän aikavälin varastokapasiteetin ennustaminen asettaa ennustetyökaluille ja niiden tarvitsemille lähtötiedoille. Lisäksi tässä diplomityössä tutkittiin, millaisia ennustyökaluja on olemassa ja voidaanko niitä soveltaa toimeksiantajan tarpeisiin.

Diplomityön ensivaiheessa tehty kirjallisuusanalyysi paljasti, että akateeminen tutkimus ei juuri tarjoa työkaluja pitkän aikavälin varastotarpeen suunnitteluun. Tarjotut mallit ja työkalut ovat usein lyhyemmän aikavälin optimointityökaluja, jotka vaativat erittäin yksityiskohtaisia lähtötietoja eivätkä näin sovellu globaaliin ylätason suunnitteluun.

Muilla teollisuudenaloilla toimivissa yrityksissä tehtyjen haastattelujen perusteella varastokapasiteetin pitkän aikavälin ennustaminen vaatii sopivan ennustetyökalun lisäksi hyvää tiedonhallintaa ja eri työkalujen ja tietojärjestelmien saumatonta integrointia. Lisäksi toimitusketjujen täytyy olla tulevaisuudessa joustavampia, jolloin varastokapasiteetin suunnittelussa täytyy tehdä tiivistä yhteistyötä asiakkaiden ja toimittajien kanssa.

Diplomityössä arvioitiin kolmen eri työkalukonseptin soveltuvuutta yhdellä toimeksiantoyrityksen toimipaikalla. Alustavien tulosten mukaan jokaisen työkalun käyttöönotto on nykyisellään vaikeaa, koska tiedonhallinta ja tietojärjestelmien integrointi eivät ole riittävän korkealla tasolla. Yksi kolmesta konseptista on alustavan arvion mukaan kuitenkin myöhemmin toteutettavissa, ja sen pohjalta on mahdollista luoda ennustetyökalu koko yrityksen käyttöön.

Asiasanat: ennustetyökalu, pitkän aikavälin ennustaminen, tiedonhallinta, varastokapasiteetti, yhteistyö toimitusketjussa

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ABSTRACT OF THE MASTER'S THESIS

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In this master's thesis was analyzed, how a large pharmaceutical company can improve its forecasting of the long-term need for warehouse capacity. To support its strategic planning, the company wanted to develop a forecast tool and process, with which the company's global need for warehouse capacity could be forecast up to the next ten years. Creating a forecast tool and process was the goal of the mother project of this thesis. In this thesis was analyzed and evaluated, what requirements the long-term forecasting of warehouse capacity needs set for forecast tools and their input data. Furthermore, this thesis evaluated, what feasible forecast tools exist and whether they can be applied at the company.

The first phase of the master's thesis showed that academic research provides few tools for forecasting long-term warehouse capacity needs. The provided models and tools are often short-term optimization tools that require highly detailed input data and therefore cannot be used for high-level global planning.

An interview series conducted with selected industries showed that the long-term forecasting of warehouse capacity needs requires not only suitable tools, but also good data management and seamless system integration. In addition, supply chains have to be more flexible in the future, which requires collaborative forecasting of warehouse capacity needs with customers and suppliers.

This master's thesis also evaluated the feasibility of three different modeling concepts for one of the client company's sites. The initial results show that currently the implementation of any of the concepts is difficult, due to problems in data management and systems integration. However, one of the concepts may provide a forecast tool to be used companywide in the future.

Keywords: forecast tool, long-term forecasting, data management, warehouse capacity, supply chain collaboration

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Terminology

Emerging markets: These are developing countries with rapidly growing economics and level of industrialization. (Wikipedia)
Generic manufacturer: This is a pharmaceutical company that does not have own research and development operations and produces only products, the patent protection of which has expired.
Make-up: This is a component of a pharmaceutical product or a finished good with set dosage, physical form and country specific attributes.
Product name: This is a pharmaceutical product's trade name or its synonym, and it specifies the product's dosage and physical form.
Research-based pharmaceutical company: This is a pharmaceutical company that develops and manufactures patent protected drugs.
Western markets: These are markets comprising North America and Western, Northern and Southern Europe, excluding the emerging markets.

Abbreviations

3PL	third party logistics provider
AI	active ingredient
ANZSIC	Australian and New Zealand Standard Industrial Classification
API	active pharmaceutical ingredient
BoM	bill of materials
EMEA	Europe, the Middle East and Africa
ERP	enterprise resource planning
GICS	Global Industry Classification Standard
ICB	Industry Classification Benchmark
IPR	immaterial property rights
IT	information technology
MTO	make-to-order
NAICS	North American Industry Classification System
non-OTC	non-over the counter
OTC	over the counter
SCOR-model	Supply Chain Operations Reference –model
SKU	stock keeping unit
WMS	warehouse management system

1. Introduction

1.1 Problem statement and goal

The end client of this thesis was a large, globally operating research-based pharmaceutical company, which for confidentiality reasons will be referred to with the pseudonym Nixoran. The company has in place a forecasting process for the short-term warehouse capacity needs, spanning up to two years. For the longer term, meaning 3–10 years, the company has currently no global planning process or tools for warehouse capacity planning. However, the uncertainty of the future needs for warehouse capacity calls for long-term planning. Nixoran wants to get a high-level global view on warehouse capacity needs. After this, the more accurate allocation and optimization of warehouse capacity could be conducted. This thesis aimed to capture and evaluate existing planning processes and tools to be used by Nixoran. A proposal for future work was given based on this analysis. Findings from academic research and other industries were used to evaluate tool concepts for the modeling of long-term warehouse capacity needs. The research questions to be answered in this thesis were:

1. *What are Nixoran's requirements for forecast models and tools for forecasting future needs for warehouse capacity?*
2. *What kind of process models and tools the academic research provides for long-term warehouse capacity planning?*
3. *What kind of process models and tools are used in other manufacturing industries, apart from the pharmaceutical industry, for long-term warehouse capacity planning?*
4. *How can the lessons from literature and other industries be used at Nixoran?*

The structure of the thesis is as follows. In chapter one are presented the thesis scope and background. Chapter two presents the research methodology. Chapter three evaluates previous research on warehouse capacity planning, with a wider look on the function of warehousing in supply chains. In chapter four are presented and analyzed the results from the industry findings. The implications and recommendations for applying the lessons from other industries at Nixoran are presented in chapter five. Chapter six presents the developed warehouse capacity modeling concepts and evaluates them. Chapter seven discusses limitations of the thesis results, further modeling tool development and research directions in the area of warehouse capacity planning.

The final goal of this thesis was to give a proposal for a modeling tool concept that on the basis of the conducted analysis can be developed further to give accurate enough estimates on the future pallet space needs of products, both current ones and those in the research pipeline.

1.2 The scope of the thesis

This master's thesis was part of a project done at the BWI Center for Industrial Management (das Betriebswissenschaftliches Zentrum, BWI) at the Swiss Federal Institute of Technology Zürich (die Eidgenössische Technische Hochschule Zürich, ETHZ). The project’s name was “Long-Range planning of Logistics capacities in the pharmaceutical industry”, and it was lead by Felix Friemann. The goal of the project was to create a tool and a process for forecasting long-term warehouse capacity needs in a pharmaceutical company.

This thesis supported the first part of the project by evaluating, if the data requirements of different tool concepts could be met at Nixoran. The concepts were developed in the mother project. The development and validation of a finished forecast tool was the goal of the mother project. This thesis provided an analysis on the requirements, benefits and deficiencies of different tool concepts using findings from literature and other industries. The evaluated tool concepts were aimed for high-level forecasting of global warehouse capacity needs. A more accurate analysis on warehouse locations and network structure would be conducted later, if the initial global forecasts showed significant changes in warehouse capacity needs. This level of detail was not in the scope of this thesis.

Figure 1 presents the general scope of long-term warehouse capacity planning, located in the area of strategic planning as opposed to short-term warehouse capacity planning. As defined by Johnson et al. (2008, p. 6), strategic decisions are often complex, have far-reaching consequences and evaluate an organization's resources. As the need for long-term warehouse capacity affects investment decisions and is linked to other long-term capacity decisions, long-term warehouse planning can be placed under the strategic planning. Stevens (1989) states that at the strategic level the focus of supply chain development should include objectives and the shape of the supply chain. Stevens describes the tactical planning as a means to find tools for realizing the strategic decisions. Operational planning is about the efficiency of the supply chain and detailed plans for operations and their control.

The tactical and operational view are outside the scope of this thesis, since the aim is to evaluate tool alternatives that will help in making strategic analyses and decisions, not implement them. Although Stevens states that supply chain efficiency belongs solely to the scope of operational planning, efficiency can be seen as a long-term strategic secondary objective.

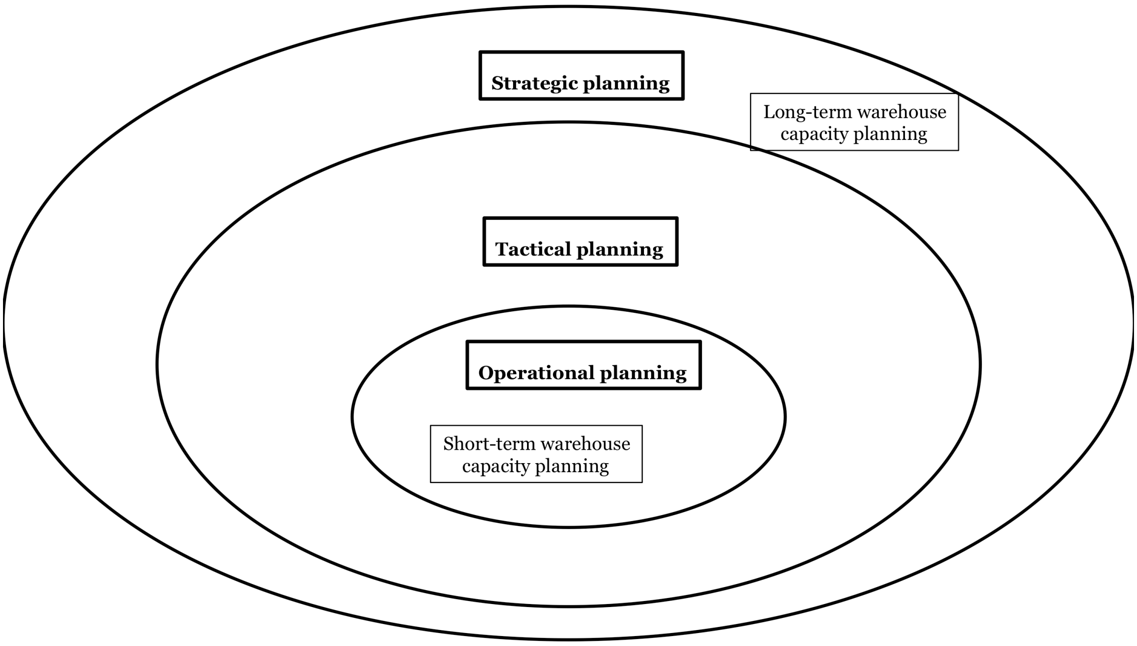

Figure 1: The scope of long-term warehouse planning in the general sphere of enterprise planning.

Figure 2 presents those sub-problems of long-term warehouse planning that are in the scope of this thesis. They are divided under headings "What?", "Who?" and "How?". This is a rough illustration of the total planning problem, linking together the purpose of planning, planning personnel and the needed tools and data. The connections between the sub-problems are illustrated by having the ovals cross each other. The sub-problems in the thesis scope are planning tools and systems, data used in planning and warehouse capacity.

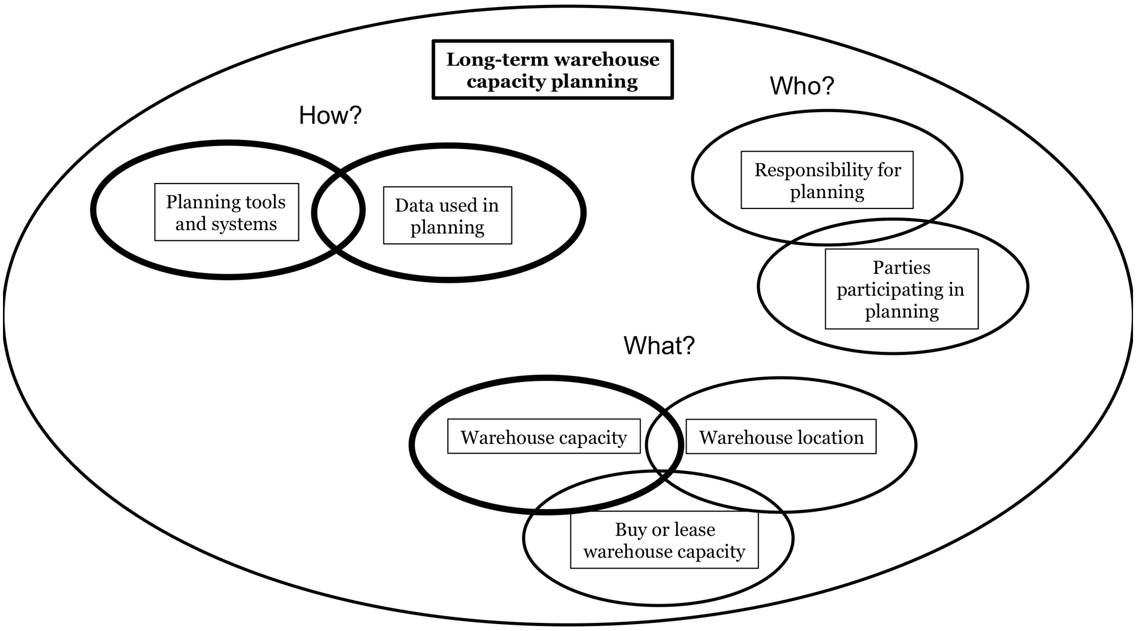

Figure 2: The thesis scope presented as selected sub-problems of long-term warehouse capacity planning.

1.3 The current state of warehouse capacity planning at Nixoran and future needs

Part 1.3 answers research question 1: "*What are Nixoran's requirements for forecast models and tools for forecasting future needs for warehouse capacity?*" The results of this part mainly rely on a pharmaceutical interview series conducted by Felix Friemann within the mother project with 11 large pharmaceutical companies.

Currently Nixoran has an established process for inventory and warehouse capacity planning for up to two years' time span. At this level, the inventory planning is done for every make-up using enterprise resource planning (ERP). The plans are based on monthly forecast data that is available at country level. This planning process provides Nixoran with the information on pallet space needs for the next two years.

For the time span of 3–10 years, Nixoran has available sales forecasts only for product names on annual level. These data are provided only for the three regions, into which the global market is divided: USA, Western Europe and Rest of the World. For the long-term, there exist no inventory forecasts. However, for the long-term Nixoran needs a global tool for warehouse capacity forecasting.

The research pipeline is uncertain and therefore its requirements for the future warehouse capacity are desirably modeled well in advance, since investing in new warehouse capacity can take many years. Yet, the time lag of research pipeline should give ample time for warehouse capacity planning.

Currently, only sales forecasts are done on a global level before broken up into regional and country level forecasts. However, other short-term forecasts are only done regionally and with site-specific systems. The ERP provider is the same for all sites, but the information used and stored in different systems and databases varies. At some sites, the ERP contains also the inventory data, while at other sites the inventory data is located at a separate warehouse management system (WMS). The local planning systems are also not standardized company wide. Although the data pieces may be inconsistent and spread among different systems, Nixoran may still possess the required data for forecasting the long-term warehousing capacity needs. Then the question is not only creating a reliable, accurate and efficient model concept, but also paying attention to data management and system integration.

1.4 The classification of warehouse capacity at Nixoran

The raw materials, semi-finished products and finished goods are stored according to their individual needs. At Nixoran there exist at least five different types of storage: room temperature storage, controlled storage, cold chain storage, frozen storage and freezers. Room temperature storage is not temperature-controlled. Controlled storage has a temperature between 2–25 degrees centigrade. Cold chain storage has a temperature between 2–8 degrees centigrade. Cold storage is kept at -20 degrees centigrade. The temperature of the freezers is kept at -80 degrees centigrade.

The temperature requirements of raw materials and products vary, but as a rule of thumb, active ingredients (AI, API), some semi-finished products and final products require at least controlled storage. Packaging materials and instruments used to administer the drugs can be stored at room temperature. Some drugs can be stored also at room temperature. The five different storage types can be divided roughly into two categories: room temperature storage and temperature-controlled storage. Room temperature storage may also be referred to as ambient storage.

1.5 The last two decades in the pharmaceutical industry

In the past, research-based pharmaceutical companies have used up to 25 % of their sales on research and development of new drugs. As the companies have been able to create and sell new high margin products on a regular basis, this strategy has been dominant among the global companies in the pharmaceutical industry. However, the globalization of markets, government regulation, and weakening patent protection of products are having a negative impact on the past strategy. In addition, companies' internal factors, like inflexible operations and the declining efficiency of new product research and development are driving the companies to find new ways to grow and sustain high profitability (Shah, 2004). Stelzl (2004) mentions that increased competition from generic manufacturers, high governmental regulation for product launches, government pressure on drug pricing, high importance of innovation and strict guidelines for product safety are the current trends in the pharmaceutical industry.

As Booth states (see (Shah, 2004) and references therein), when the pharmaceutical companies were still able to rely on their product development funnels to continuously produce new high selling products, company management in the industry focused mainly on marketing and sales. In the past the more localized markets, longer lasting and stronger effective patent protection and looser government regulations supported this strategy. However, as the previous advantages have gradually eroded during the last two decades, pharmaceutical companies have started to search for improvements in operational efficiency.

Nowadays generic manufacturers can produce drugs without the burden of high research and development costs, product research is not as fruitful as in the past and governments are regulating the price premiums of drugs. Therefore, research-based pharmaceutical companies should investigate the possibilities provided by operational efficiency. Consequently, supply chain thinking and management are becoming more important also in the pharmaceutical industry. Supply chains should not be seen only as logistics operations for meeting production targets; rather, a good supply chain is a means to deliver better products more efficiently.

Not only has the competition and regulation in the pharmaceutical industry changed. The market structure also has changed, since demand has started to increase at the emerging markets. This has lead to a polarization where the western markets and emerging markets have their own requirements that have to be met with different value offers. This means that not only do the required products differ, but also the whole supply chain is different. In some markets, the consumer is the primary customer while in others physicians and pharmacists may be the target customers of a drug manufacturer (Stelzl, 2004). These differences place their own restrictions and requirements on the supply chain and warehousing.

1.6 The modern pharmaceutical supply chain

According to Shah (2004), a typical modern pharmaceutical supply chain can consist of up to five different nodes:

1. Primary manufacturing
2. Secondary manufacturing
3. Market warehouses and distribution centers
4. Wholesalers
5. Retailers and hospitals.

Primary manufacturing is responsible for making a drug's active ingredient. Primary manufacturing is traditionally done in batch processes and the processing cycles often take multiple work shifts. Inventories between process stages are kept high for multistage processes and semi-finished products often have to pass an intermediary quality control. One plant often produces multiple products, so that the capital costs can be distributed for a wider product range. In order to avoid product cross-contamination, the manufacturing equipment have to be thoroughly cleaned between production runs. This causes long downtimes for product changeovers, in the order of multiple weeks. This encourages companies to run long manufacturing campaigns to keep the equipment utilization rate higher, which in turn leads to very high inventories. Commonly a one-year's production for a single product can be done in a single production campaign (Shah, 2004).

In secondary manufacturing, the AI is combined with additional inert materials to produce the final product. The whole process of secondary manufacturing can include, for example, granulation of the AI, compression into tablet form, coating, final quality control and packaging. Usually secondary manufacturing is geographically located away from the primary manufacturing to optimize taxation and take advantage of transfer pricing. In addition, often one primary manufacturing site serves multiple, locally operating secondary manufacturing sites. Transportation times between manufacturing sites are usually one to two weeks by sea freight, which is the regular operation mode, and one to two days by airplane (Shah, 2004). From secondary manufacturing, the products are taken to distribution centers to be distributed to customers.

The structure of the pharmaceutical supply chain makes the need for warehouse capacity difficult to model. Since primary manufacturing is carried out in larger campaigns, the inventory levels and needed warehouse capacity may experience large fluctuations. Because secondary manufacturing can be located away from primary manufacturing, the same warehouse capacity may not always be used for raw materials and finished goods, even if safety precautions would allow this. Optimizing manufacturing costs by taking advantage of transfer pricing and differences in taxation between countries may require excess warehouse capacity. For example, warehousing a site's own production and the production of another site for taxation reasons could lead the first site having double the needed warehouse capacity. The other site may still have the warehouse capacity to store the amount of goods earmarked to it.

1.7 Business characteristics of the pharmaceutical industry

Traditionally consumers have had low price sensitivity for pharmaceutical products' prices for two reasons. First, in some markets a third party often pays for prescription drugs. For example, in the United States an insurance company usually pays for the drug. Second, prescribing physicians choose the drugs, which leaves the end users with little choice (Stelzl, 2004). As indicated in the interview series conducted by Felix Friemann within the mother project, patent protected drugs account for the majority of the revenues of research-based pharmaceutical companies: on average about 80 % among the interviewed companies. Therefore, it is in the interests of the pharmaceutical companies to uphold the current situation and inhibit the increase of price awareness among consumers. Although the described market structure is not prevalent in all markets, it is the market structure in the United States. Since the United States is the single biggest market for drugs with 28 % of global sales in 2009 (IMAP, Inc., 2011), the practices there largely dictate the way, in which pharmaceutical companies approach their customers and the end-users of products.

The price pressures, political agendas and safety issues form a mixed, and partially controversial set of requirements. For example, governments require a new drug to have significant advantages over existing ones before it can be launched. Yet, the governments are simultaneously issuing stricter control on drug prices to lower them. Effectively, the governments are sometimes asking for better drugs with lower prices, although there are few low-hanging fruit left in the field of pharmaceutical research. Due to the increasing governmental requirements and decreasing efficiency of research and development, the consolidation in the pharmaceutical industry has been significant: the top 10 % of pharmaceutical companies by revenue made nearly 60 % of global sales in the year 2004 (The Health Strategies Consultancy LLC, 2005).

The pharmaceutical supply chain has complicated pricing policies (The Health Strategies Consultancy LLC, 2005), which can lead to a lack of collaboration in demand and supply planning and are likely to lead to a sub-optimal supply chain, since each member tries to maximize individual profit. In addition, as Lee et al. (1997) states, fluctuating prices and the lack of information sharing and collaborative planning increase the bullwhip effect, which is one of the main reasons for excess inventories. The lack of transparency can therefore limit the effectiveness of even advanced forecast models, making supply chain collaboration a precondition for accurate planning.

Since time-to-market is the main driver in the pharmaceutical industry (Shah, 2004), the importance of a flexible and reliable supply chain is increasing. During the effective period, sometimes only two to four years, of the patent protection even small delays can significantly decrease profits. Therefore, with high-margin patent protected drugs meeting all the demand is the top priority, which is achieved via a flexible and reliable supply chain. Conversely, for low-cost generic products the supply chain has to be efficient and can be more inflexible in order to incur low costs, as per the categorization of products in Fisher (1997).

1.8 Product characteristics of pharmaceutical products

Stelzl (2004) divides drugs into four categories: conventional non-prescription drugs (over-the-counter, OTC) conventional prescription drugs (non-OTC), biological agents and vaccines. OTC drugs are usually relatively cheap while the newest drugs for rare illnesses are extremely expensive. Fisher's (1997) method of categorizing products into functional and innovative is not directly applicable to the pharmaceutical industry. On one hand, pharmaceutical products are innovative, since new patent protected products may have little substitutes, can collect price premiums and the effective patent protection of a few years can be the product's effective life cycle in the market. On the other hand, pharmaceutical products may at the same time be functional, since during the short life time of a patent protected drug the demand may be quite stable and plummet only after patent expiration. The products may also turn into functional after their life cycle as innovative products, and continue to have high demand if substitutes do not gain market share. Consequently, the supply chain for a pharmaceutical product is dependent on the stage of the product's life cycle and should be adaptable from flexible to efficient.

In the pharmaceutical industry, new product development is product oriented because of the uncertainty in research and development. Customer oriented product development is difficult to adopt, since finding the right molecule for a precise customer need would be extremely difficult. In the pharmaceutical industry immaterial property rights (IPR) are extremely important, since the relatively few successful product launches have to cover the costs of all the research and development (Stelzl, 2004).

1.9 Obstacles for improving warehouse capacity planning in the pharmaceutical industry

The pharmaceutical industry has had little incentives to become more efficient since time-to-market has been the main industry driver; the first to sell the new product often receives the highest margins. The usage of manufacturing campaigns and the need for near perfect service levels has lead to very high inventories, and possibly to excess warehouse capacity. Also, because of the complex and hardly transparent pricing policies the need for price competition was less of an issue in the past. Furthermore, minimizing taxes could have lead to operationally illogical solutions, but higher profits. Finally, the importance of IPR has probably hampered information sharing between suppliers and customers, leaving the supply chain misaligned.

As a conclusion, research-based pharmaceutical companies have many reasons to pursue operational efficiency; inflexible production capacity, changing market structure, price erosion and increasing competition all require companies to re-think their business logic and start operating more efficiently. At the same time some of the current industry structures are discouraging these improvements: market drivers, batch production, the peculiarities in pricing, the multitude of parties with differing interests and possible mistrust regarding information sharing all are in the way of improving supply chain efficiency and effectiveness. Without a new mindset, the supply chain cannot be seen as a collaborative network of entities with mutual instead of mutually exclusive interests. Before this change in thinking takes place, increasing the supply chain effectiveness and efficiency in the long-term, including having the correct amount of warehouse capacity, cannot be achieved. For Nixoran, starting the project for forecasting long-term needs for logistics capacity is the first step in to the right direction.

2. Methodology

2.1 Systems Engineering methodology

This thesis was carried out using the Systems Engineering methodology as the general methodology for problem and goal statement, objective setting, situation analysis and solution development, solution evaluation and solution selection. For more information on the Systems Engineering methodology, see for example Züst and Troxler (2006).

According to the Systems Engineering methodology, the target system of this thesis is the long-range warehouse capacity planning process at Nixoran, and the analysis and area of intervention were delimited according to Figure 2. From the analysis of the current system were developed the objectives and goals for the thesis. After this, improvement possibilities for long-term warehouse capacity planning were identified, and recommendations for their implementation were given.

2.2 Connection to the mother project

This thesis provided the mother project an analysis on the existence and applicability of planning concepts and tools for long-term warehouse capacity at a large pharmaceutical company. The mother project's goal was to provide Nixoran a forecast tool and process, and this thesis helped in identifying the requirements for a good forecast model. Nixoran's ability to meet these requirements was also analyzed, and current problem areas were identified. The requirements were found via a literature review and by analyzing planning processes and tools from other industries. The lessons from literature and other industries provided clear requirements for a good planning process and tool. The requirements were also used to analyze forecast tool concepts developed in the mother project, and make a proposal for further forecast tool development.

Based on one of the concepts, a first forecast tool prototype was developed in this thesis and given for further development.

2.3 Literature analysis

A literature analysis was conducted to find best practices for long-term warehouse capacity planning and to answer research question 2: "*What kind of process models and tools the academic research provides for long-term warehouse capacity planning?*"

The contributions of articles from peer-reviewed journals were analyzed, as well as those of other articles, guidelines and books on warehouse design and planning. The findings of the literature analysis were compared against Nixoran's requirements to choose possible tools or tool concepts. Since the contributions from literature were not expected to be complete, the answers for the remaining questions and gaps were searched for via an interview series.

2.4 Interview methodology

The interview part of this thesis aimed to answer research question number 3: "*What kind of process models and tools are used in other manufacturing industries, apart from the pharmaceutical industry, for long-term warehouse capacity planning?*"

The goal of the interview part was to gather knowledge on the warehouse capacity planning processes and tools used in other industries and benchmark those against the tools and processes used at Nixoran. From this were drawn recommendations for the long-term warehouse capacity planning tools and process. As stated by Leibfried and Mcnair (see Bhutta and Huq (1999) and references therein), benchmarking against other industries is a valid approach for process development: finding and applying best practices from other industries provides more learning opportunities than benchmarking within one company or industry.

By benchmarking against other industries, it is possible to find not only good planning processes and tools, but also metrics for defining the quality of a planning tool. For example, the features of a planning process can be compared against its performance. When done over multiple companies, some general descriptive features can be related with good planning tools. Although this may provide highly subjective metrics, many metrics can be argued to be subjective; the metric just has to be relevant, precise and accurate enough.

Since the most suitable industries and the actual processes used for warehouse capacity planning were unknown, an explorative approach was chosen. As described by Silverman (2006), an explorative study should be used when there is no initial research hypothesis and little initial knowledge on the topic. The study was conducted as a structured interview with both fixed-choice and open-ended questions. As Silverman states (2006), the respondents' answers to fixed-choice questions are more easily comparable, but open-ended questions leave room for unexpected, yet important viewpoints, and allow the collection of qualitative information. Four of the nine interviews were conducted face-to-face since traveling to these companies was feasible. Other five interviews were conducted via telephone.

The major risks of the interview approach are interviewer and interviewee caused errors and the errors in interview planning and schedule. The interviewer errors include interviewer bias and the inconsistency in carrying out the interviews; the interviewer can inadvertently and unknowingly hint the respondent to give certain types of answers, or the interviewer may present the questions to the respondents in slightly differing ways, which will make the interview data less comparable. The respondent may knowingly or unknowingly provide answers that he expects to satisfy the interviewer, although the answers may not be entirely truthful. Also, the interviewees may understand the used terminology in different ways, which will worsen the data quality. To counter the possible errors, only one person conducted the interviews using a per industry standardized interview schedule. During the interviews, the interviewees' understanding on the terminology was verified, if it was to be doubted, that their understanding differed from that of the interviewer. The general interview template is presented in Appendix B. The content, form and layout of the interview template were developed in cooperation with Felix Friemann. For more information on doing interview studies, see for example Silverman (2006) or Weiss (1995).

2.4.1 Company interviews

Since the purpose of the interview series was to get a wide, although not necessarily complete view on the topic, the target was to get an informative group of interviewees, rather than a representative one (Weiss, 1995). Thus, four different industries and two to three companies from each industry were chosen for the interviews. Having two to three similar companies provided a broader view on industry related planning processes and tools, than an interview with only one company per industry. Cross-industry evaluation revealed differences between industries and possible reasons for them.

Suitable industries for the interview series were identified via a comparison of industry characteristics. The characteristics were compared against those of the pharmaceutical industry on a rough level to ensure that an industry was similar enough to the pharmaceutical industry. The reason for this was that similar enough industries were expected to provide applicable planning processes and practices. Consequently, an industry with high-value products and long lead times would more likely provide suitable planning practices for the pharmaceutical industry, than one with low-value products and short lead-times.

Rough similarities between industry characteristics do not guarantee the existence of similar processes and tools, since also the more detailed product characteristics, market structure and other factors affect the supply chain and warehouse capacity planning. Also, some practices from dissimilar industries may be applicable when adjusted for the pharmaceutical industry.

The initially previewed industries for the interview series of this thesis were:

1. Jet engine manufacturing
2. Food processing
3. Retail
4. Automotive
5. Airlines
6. Petroleum
7. Semiconductor

Table 12 in Appendix A presents the comparison of industry characteristics of the seven industries. Some of the variables used in the comparisons in Table 12, like production volume, were ambiguous, since some industries produce unit products while others produce continuum materials or services. All the comparisons were done relative to the selected group of industries.

The previewed industries were loosely named with layman terms, and the compared characteristics were chosen among those pertinent to the pharmaceutical industry. The information on different industries was obtained from publicly available research papers, articles and industry reports. After choosing the four industries for the interviews, the final classification of these four was done using the Industry Classification Benchmark system (ICB), developed by FTSE International Limited for industry classification purposes needed in composing and managing stock indices. For more information on ICB, its structure and usage, see for example FTSE International Limited (2010).

From the seven previewed industries presented in Table 12, two were chosen for the interviews: automotive and semiconductors. Based on recommendations received from Nixoran two more industries were chosen outside of the initially reviewed industries: cosmetics and high-technology electronics. The cosmetics industry has relatively high-value products and it requires temperature controlled warehouse capacity. High-technology industry also has relatively high-value products, and it may provide insights into supply chain collaboration. Thus, both were seen as promising participants. Initial expectations on the interview findings are briefly discussed in part 2.4.3.

The goal was to interview globally operating companies to get a view on global warehouse capacity planning. Unfortunately, this goal was not completely met and smaller Swiss companies were included in the study. The four interviewed industries were:

1. Automotive
2. Cosmetics
3. High-technology electronics
4. Semiconductor

The interviewed companies were acquired via e-mail and telephone contacts. The contact information was received from a database at BWI ETHZ, company web sites and LinkedIn web service. Over 100 individuals in over 30 different companies were contacted. The contacted and later interviewed persons usually held a position in the development and management of regional or global supply chains. Those individuals choosing to participate received the interview questions in advance. Two companies from the automotive, three from cosmetics, two from high-technology electronics and two from semiconductor industry were interviewed. On average, the interviewees had been working in their respective industries over 13 years, with a range of 2–26 years.

The interviewed companies were coded with letters from A to I to keep the individual results confidential. The interviewed companies were sent the initial interview results for review and confirmation. Two companies did not confirm the initial interview results, so for these two only preliminary results were available. These two companies were company A and company F according to the company coding.

2.4.2 Remarks on the industry classifications

The ICB uses the term industry as an umbrella term for a variety of companies engaging in roughly the same area of business, for example consumer goods. Some other classification systems, like the Global Industry Classification Standard (GICS), use the term sector for this level of classification (MCSI Incorporated, 2013). Conversely, the most granular level in ICB is called sub-sector, while in GICS the corresponding term is industry. While this thesis uses the term industry, unlike the ICB, to refer to the more granular classification level, the ICB classification was chosen, because the ICB sub-sector classifications for the interviewed companies were better available than the corresponding GICS classifications, thus allowing the verification of company relevance. Most of the interviewed companies are listed in the ICB-based indices at the STOXX Limited web site (2013). In the cases of two cosmetics companies, one semiconductor company and one high-tech electronics company the ICB classification was not available, due to the companies being too small to be included in the indices. Therefore, these companies were classified by assigning each company to an ICB sector best describing each company's operations. The two cosmetics companies could be classified with high confidence, since other cosmetics companies are classified in the FTSE indices under the ICB Personal Goods -subsector. The semiconductor company was also confidently classified to the ICB Semiconductor -subsector. The high-tech electronics company was placed under ICB Electronic & Electrical Equipment -sector. The company was not assigned an ICB subsector to avoid possible classification errors. Also, the more granular classification of the company was not necessary for the successful categorization of the companies.

The interviewed companies and their industries, according to the initial layman classification and ICB classification, are summarized in Table 13 in Appendix A. Although one high-tech electronics company was placed into the ICB sector of Electronic & Electrical Equipment, it was categorized together with the ICB Computer Hardware -subsector under the layman classification of high-technology electronics industry, since the company assembles complicated electronic circuits. Thus, the used parts and final products are quite similar between the two companies, although the customer base and business logic are different. Nevertheless, the warehouse capacity planning was expected to be somewhat similar between the two companies, although far from identical. To support this approach, an example of large differences within ICB subsectors can be given. For example, two of the interviewed cosmetics companies both belong to the ICB Personal Goods –subsector, but one serves consumers directly while the other supplies business customers.

2.4.3 Expectations on interview findings

The automotive industry was expected to provide insights especially on the effect of product complexity on warehouse capacity planning, since automobiles consists of thousands of parts. Final goods in the pharmaceutical industry can consist of dozens of individual components, which makes the managing of aggregate warehouse capacity complex. Also, the product life cycles in the automotive industry are long like in the pharmaceutical industry. Therefore, the automotive industry could provide insights in to increasing the accuracy of long-term planning as new products near their launch.

The cosmetics industry was chosen especially due to some similar characteristics with the pharmaceutical industry; both manufacture final products from chemicals. Both industries also have products that are relatively small but valuable, and both handle raw materials and products that require special storage conditions, like temperature control.

The high-technology industry produces moderately valuable and complex final products. Like the automotive industry, the high-technology industry might provide tools and processes for managing the product complexity in warehouse capacity forecasting. The short product life cycles in the high-technology industry require some flexibility in changing from one product generation to another, which could provide valuable lessons. Due to short product life cycles the time-to-market is likely an important driver in the industry, similar to the pharmaceutical industry, which means that warehouse capacity should not be a bottleneck during product launches.

The semiconductor industry has moderately valuable products that have short life cycles, which requires the flexibility to change quickly enough from one product generation to another. Therefore, the industry could provide tools and processes for improving the flexibility in the supply chain and warehousing. In the pharmaceutical industry, more flexible warehouse capacity could decrease warehousing costs while still providing high service levels.

2.5 Forecast tool concept development and evaluation

The literature and interview results were used to establish requirements for a good model for long-term warehouse capacity planning. These requirements were then combined with the initial requirement of tool applicability with differing data inputs. Based on the currently available data at Nixoran, different concepts for using available data to model warehouse capacity needs were developed mainly in the mother project. In this thesis, the concepts were evaluated against the established requirements and each other. Three concepts were developed and their strengths and weaknesses analyzed using the interview results and the current data availability at Nixoran. In this thesis, the data from Nixoran was used only for concept development and initial testing of concept feasibility regarding data availability. The concepts’ accuracy was not tested.

3. Previous research on supply chain and warehouse capacity planning

3.1 The scope of the literature review

This chapter presents the findings from academic research and its implications in the field of warehouse planning, with focus on long-term warehouse capacity planning. From the results of previous research were selected those applicable for the thesis problem. Finally, the areas lacking in research that are relevant to this thesis are presented and the implications are discussed. This chapter answers research question 2: "*What kind of process models and tools the academic research provides for long-term warehouse capacity planning?*" and research question 4: "*How can the lessons from literature and other industries be used at Nixoran?*" regarding the literature contributions.

3.2 The purpose of warehousing

One key aspect of increasing supply chain performance is having the correct amount of warehouse capacity. Dolgui and Proth identifies (2010, p. 422) nine reasons for using warehouses and inventories, including smoothing the difference between demand variability and supply chain response time, the usage of modular manufacturing and to supply seasonal products all year round. Thus, the purpose of a warehouse is to bridge the gaps between the supply chain activities, make the operations flow smoothly, increase service levels and to stabilize pricing by decreasing scarcity.

Strack and Pochet (2010) states that the required service levels mainly dictate the need for warehouse capacity. Because in the pharmaceutical industry the final products are used for treating people, stock-outs can be seen as unacceptable from a social and ethical viewpoint. This means that the companies have to guarantee the availability of any given product and, combined with inflexible batch production, the stocks for these products are often kept very high. Although lower inventory levels and minor stock outs might be economically justified, the social and ethical aspects prohibit this approach. A more accurate forecast on warehouse capacity needs will give a company the possibility to adjust their inventories and warehouse capacity without sacrificing high service levels or incurring excess costs.

Since warehouses can hide problems, like insufficient information sharing in the supply chain, the existence of storage space has to be carefully justified. The space used for warehousing has to guarantee the warehouse's flexibility, be optimally utilized, make flows simple, make the circulation of people and material efficient, and adhere to security requirements. Storage can be dedicated or shared; in shared storage, the exact layout is not fixed, but individual products can be stored at different locations at different times. A dedicated storage has fixed storage zones for all products. Shared storage is usually more cost-effective but also more difficult and complicated to manage. (Dolgui & Proth, 2010, p. 432-434)

3.3 Warehouse design and planning

Since warehouses in themselves are often non-value adding parts of the supply chain, the need for them is not a primary need, rather derived from inventory needs. Inventories have many of the same problems and requirements as warehouses and the two are strongly linked: a warehouse is the inventory’s physical location.

In academic research, inventory and warehouse problems have been widely studied, because lowering the inventories helps reduce capital costs and find the root causes for high inventory levels. Eliminating these root causes improves supply chain performance. (Dolgui & Proth, 2010, p. 109)

According to Rouwenvorst et al. (2000), the majority of research on warehousing concentrates on well-defined problems and have an analytical approach. The other, design oriented approach tries to create a synthesis of the different technical systems and planning and control procedures, that can be used in warehouse design. The analytical approach provides many mathematical models for optimizing inventories. These models often use as inputs inventory levels, demand, number of manufacturing stages, product-mix and costs (Dolgui & Proth, 2010, p. 109). There are also a number of models for optimizing the static warehouse capacity: for example, see Rosenblatt and Roll

(1984) or Rao and Rao (1998). Unfortunately, the supply chain research has been lacking an approach that would combine the analytical and design approach (Rouwenhorst et al., 2000), although the combination could provide superior results as opposed to using either approach alone. For example, naming the technology and processes needed to engage in more advanced mathematical modeling of warehouse capacity would help implement the more elaborate modeling tools provided in academic research. Of course the advantages of more sophisticated models are not always obvious or easily verifiable in real life, so their implementation does not guarantee better performance in the supply chain and warehousing.

The planning for manufacturing capacity and inventory policies should be made simultaneously to minimize their total costs. Often the decisions are made separately, because simultaneous modeling is deemed too difficult, or the interaction of the two decisions is regarded as insignificant. Managers often emphasize the high costs of unused manufacturing capacity but fail to realize, that the chosen inventory policies affect the capacity utilization (Bradley & Glynn , 2002). Therefore, the importance of warehouse sizing and design goes often unnoticed.

Cornier and Gunn (1992) classifies warehousing problems into three categories: throughput capacity, storage capacity and warehouse design. The solutions for the storage capacity problem usually either minimize total warehousing costs or maximize service level. However, current research often concentrates on optimizing warehouse sub-systems, which may yield sub-optimal results for the whole warehousing system. Gu et al. (2010) presents a more granular view on warehousing problems, giving five different sub-problems: overall warehouse structure, warehouse sizing, detailed layout, equipment selection and choosing the operational strategy. These five problems are strongly linked, since, for example, sizing and layout are partly dependent on each other.

3.4 Warehouse sizing and capacity need estimates

For warehouse sizing Gu et al. (2010) presents two scenarios: either inventory levels are determined by external requirements, or the warehouse controls the inventory policy. Rouwenhorst et al. (2000) states that warehouse design is actually dictated by decisions made in production planning which include, for example, production capacity, batch sizes and product mix. These pieces of data are used as inputs for the warehouse design problem at the strategic level. The design problem also uses order quantities and order intervals as input data. The solution to the problem provides requirements for warehouse process flow and an inventory system (Rouwenhorstet al., 2000).

Smith (2003) gives a high-level concept for a warehouse capacity decision from a case study in the pharmaceutical industry. The question is whether a company should invest in new warehouse capacity or outsource it to a third party logistics provider (3PL). The concept can be described as having four distinct steps:

1. Create a storage model based on production plans.
2. Calculate capacity needs.
3. Develop alternative scenarios.
4. Choose the best alternative and implement it.

In the first step, the monthly production over the planning horizon of the next five years is used as input to create a storage model. The storage model incorporates the storage needs for raw materials, work in progress and finished goods. The storage model also considers the special requirements of different goods, for example temperature control. In the second step the needs for storage space in square feet is calculated for all different storage conditions. In the third step, the costs of different scenarios are analyzed. The scenarios include the current situation, which is the base case, and the other possible solutions, for example, utilizing a third party logistics provider (3PL) or constructing a new central warehouse facility. For each scenario, the costs of transportation, capital and operational costs and depreciation are calculated. In the fourth step, the scenarios are compared against the current situation using internal rate of return and net present value methods to choose the best alternative.

Battersby and Garnett (1993) provides a more detailed, nine step guideline for building a warehouse for drugs. The steps are, as applied to the research problem of this thesis:

1. Identify the drugs to be warehoused.
2. Review the existing warehouse system and evaluate it against demand and against transportation networks.
3. Adopt appropriate purchasing and inventory control policies.
4. Adopt a policy for stock administration.
5. Decide, which drugs and how much are to be stored.
6. Establish transport volumes.
7. Decide the warehouse size.
8. Design the warehouse.
9. Implement the plans.

Battersby and Garnet (1993) also presents a formula for calculating the volumetric warehouse capacity needs. The formula is:

$$V_{box} = D_a * P_t * P_p * K_p \tag{1}$$

where

V_{box}	is the annual boxed gross volume of a product.
D_a	is the annual unit demand of a product, for example 1000 tablets.
P_t	is the product type factor, which gives the net volume for a chosen product type, for example the net volume of 100 tablets of a given product.
P_p	is the presentation factor that adjusts the volume of the product type, for example taking into account the empty space between capsules in a pack.
K_p	is the outer pack factor or kit pack factor. The outer pack factor adjusts the product’s net volume into gross volume, including the package. The kit pack factor gives the gross volume for products that come in kits with other equipment, for example needles and syringes.

To get the required warehouse capacity, the annual boxed gross volume is averaged into monthly throughput, and the desired safety stock level and the re-stock interval are taken into account. Thus, the formula for the needed warehouse capacity from Battersby and Garnett (1993) is:

$$W = \frac{V_{box}}{12} * (S + Re) \tag{2}$$

where

W is the required warehouse capacity in volumetric units.

S is the safety stock in months.

Re is the re-stock interval in months.

The safety stock is a matter of inventory policy as is the re-stock interval. For example, for the widely used (R, Q) policy, where R is the re-order point and Q the re-order quantity, exist analytical formulae to determine the optimal values for R and Q (for example, see Axsäter (2006, Ch. 6)). When R is interpreted as the safety stock, the value for S in formula (2) follows directly.

Formula (2) gives the warehouse capacity in volumetric units so it has to be adjusted with a pallet factor to convert the volumetric units into pallet spaces. When formula (1) is adjusted with a pallet factor, the result from formula (2) will directly give the warehouse storage needs in pallet spaces. This pallet factor is defined by setting policies for the pallet fill level for all the different product types. The pallet factor is:

$$PF = \frac{1}{N * PV} \tag{3}$$

where

PF is the pallet factor.

N is the number of product units in a given product type. For example, for a pack of 1000 tablets $N = 1000$.

PV is the number of packs of a given make-up that can be fitted on a single pallet.

For formula (3), the value of PV is individual for every make-up that differs in outer dimensions from the others. The PVs can be obtained from master data where the dimensions for every pack type are stored. If this data is not available, the outer dimensions of all different pack types have to be measured, and the number of packs per pallet has to be decided and optimized.

Using formula (3), the three factors P_t, P_p and K_p in formula (1) can be omitted and thus:

$$A_p = D_a * PF \qquad (4)$$

where

A_P is the annual need for pallet spaces for a single make-up.

Thus, formula (2) becomes

$$W_P = \frac{A_P}{12}\,(S + Re) \qquad (5)$$

where

W_P is the required warehouse capacity in pallet spaces.

The parameters used in Battersby and Garnett (1993) have to be established via measurements before they can be taken as standards and used in a straightforward fashion. This means that the parameters have to be measured and defined for all used product types, make-ups and kit combinations. Although the formulae (4) and (5) are presented for finished goods, they can be used for raw materials and semi-finished goods. The demand for them is derived from the demand for finished goods with the help of bill of materials (BoM), and the pallet factor *PF* for them is also established. The safety stock and re-order interval can be calculated from the derived demand data.

3.5 An analytical tool for optimizing the warehouse size

For the warehouse capacity problem Rosenblatt and Roll (1984) develops a solution procedure that minimizes the total costs when warehouse size, warehouse layout and storage policy are considered simultaneously. The model assumes that the data on the distributions of the arrival, composition and retrieval of the goods are known. Also, the cost model for the total warehousing costs is assumed to be known, consisting of warehouse investment and material handling costs, shortage costs and storage policy costs. The total cost function is:

$$TC(K,\rho) = [C_1(K,\rho) + C_2(K,\rho) + C_3(K,\rho)] \tag{6}$$

where

TC	is the total costs of the warehouse.
K	is the warehouse capacity in chosen storage units.
ρ	is the randomness factor that tells, what portion of the warehouse can be used for random storage policy. If the number of different storage zones is r, then $\rho = \frac{1}{r}$
C_1	is the warehouse construction and warehouse material handling costs.
C_2	is the shortage costs incurred from shipments that cannot be accommodated.
C_3	is the storage policy costs, partly based on the warehouse's layout and zoning.

The goal is to minimize TC in formula (6) for a desired service level. The exact procedure and the detailed formulae are available at Rosenblatt and Roll (1984).

3.6 Gaps in supply chain and warehouse management research

Dolgui and Proth (2010, p. 112) points out that the mathematical models provided by academic literature seldom correspond to real inventories. Reasons for this include the continuously changing real-life environment, over-simplification of causal relationships and a mathematical model's inability to effectively manipulate qualitative data. Further deficiencies include the premise of a constant product portfolio, which in the scope of this thesis is an unreasonable assumption. Similar concerns arise regarding the warehouse sizing models presented in parts 3.4 and 3.5. Optimization models may also require the use of simpler heuristics to calculate initial values for the iteration, so that the use of multiple models may be necessary.

The model in Rosenblatt and Roll (1984) is suitable for short-term optimization, but not for long-term forecasting with an uncertain product pipeline. The model uses as inputs fixed distributions on the arrival and departure of goods, meaning data that are seldom available at the early stages of product research and development. Furthermore, the initial warehouse size and stock policy have to be decided using some other method, which makes the model unusable for initial forecasting of warehouse capacity needs. Being a mathematical model, rather than a more holistic process model, the different parties and resources needed in the optimization process are not presented.

According to a literature review by Osborn and Nault (2012), among the most popular research topics in supply chain management are resource utilization and pricing. These include problems on optimizing existing resources, acquiring new resources, cost cutting and revenue models. The concentration on certain industry sectors is also significant. Manufacturing and retail trade combined cover over 75 % of the research over different sectors. Of all sectors, electronic, grocery and general merchandise together account for over 50 % of research. An even more granular classification based on product type showed that less than two percent of research discusses the pharmaceutical industry. Burges et al. (2006) presents similar findings on the coverage of supply chain research over different industries.

In Osborne and Nault (2012) the research problem, not the target company's sector, dictated, to which sector a research paper was classified. For example, research done in a retail trade company could be placed under transportation and warehousing, if the research problem concentrated on the transportation of goods. In Burges et al. (2006), the papers were classified according to the sector that brought the majority of a company's revenue.

While Osborne and Nault (2012) classifies research according to the problems discussed, for example resource utilization, uncertainty and demand fluctuations, Burgess et al. (2006) examines the viewpoints taken in research; whether a paper is descriptive, provides definitions, takes a theoretical perspective or addresses research methodology. Another difference between the papers is the use of different industry classification systems. Osborne and Nault uses the North American Industry Classifications System (NAICS, see (NAICS Association, LLC)) while Burgess et al. uses the Australian and New Zealand Standard Industry Classification (ANZSIC, see (Australian Bureau of Statistics)). However, the two classification systems are quite similar on the sector level, with the NAICS having a bit more granulated division into 20 sectors compared to the 17 used in ANZSIC. Also, the difference between the unit of analysis does not influence the observed distribution of studied sectors in research. These facts support the validity of the observed similarities in the results of these two papers.

Sachan and Datta (2005) identifies the most popular research methods in supply chain research to be surveys, interviews, simulation and mathematical modeling. Wu et al. (1997) mentions that research in manufacturing logistics, including warehousing, usually discusses small systems and static problems, and empirical research is lacking in quantity.

3.7 Findings of the literature analysis

The major findings of the literature analysis were divided into two categories: general research directions and warehouse modeling and sizing. The main findings on the general research directions in supply chain research are that:

1. The pharmaceutical industry has not been a popular target for researchers in supply chain management and warehouse design.
2. In general, industry practices in warehousing are not widely captured and analyzed, which mitigates their dissemination.

The first finding implies that the special characteristics of pharmaceutical industry are seldom accounted for in research, which may significantly decrease the applicability of research results in the pharmaceutical industry. Thus, it is extremely important to critically evaluate the applicability of generalized models and tools for the pharmaceutical industry. The second finding implies that the different tools and processes for warehouse capacity planning in different industries have not been extensively researched. Therefore, the successful adoption and adaptation of the results of academic research have not been evaluated. Also, the tools and practices developed in industries are not well documented and shared, although their study could provide valuable lessons for companies. For example, the long-term warehouse planning tools and processes in the automotive industry could be analyzed and then adapted for use in the pharmaceutical industry.

The findings on warehouse modeling and sizing were that:

1. The research on warehousing concentrates on small sub-problems instead of holistic models, although the simultaneous design of larger systems could yield higher service levels and lower costs.
2. Mathematical models have many shortcomings in modeling real inventories and warehouses.
3. Warehouse design models concentrate on resource optimization, are often complex and require detailed input data.
4. There exist some simple models, which may be used for long-term warehouse capacity planning.

The first three findings tell that mathematical models are often unsuitable for forecasting the long-term needs for pallet spaces. The models often concentrate on small sub-problems instead of a company's global warehouse capacity and make assumptions that are usually acceptable only for the short-term. For example, the product portfolio cannot be expected to be static on a 10-year time span, nor is the demand distribution of new products known. Additionally, the provided models usually either maximize the warehouse capacity utilization or minimize the related costs, but do not provide a process or tools for evaluating the rough long-term warehouse capacity needs on a company wide level. The last finding tells that some simple models for the forecasting of long-term warehouse capacity can be found in literature, although they may be rare. The model in Battersby and Garnett (1993) is with some adaptation probably applicable for long-term warehouse capacity forecasting.

Although the models for forecasting long-term warehouse capacity needs in the academic research are rare, the applicability of the models is also dependent on the target company. If the company does not have the necessary data inputs for a model, the company has to first establish data collection, storage and sharing processes to enable the usage of new forecast models and tools. Looking into the warehouse capacity planning research and models, the following data requirements for forecasting pallet space needs can be drawn:

1. Warehouse design and capacity calculations are dependent on manufacturing parameters.
2. The reciprocal effects and data requirements between warehousing and other operations have to be identified, analyzed and taken care of.
3. Preferably daily warehouse throughput is recorded to calculate average inventories and their variation.
4. Product and component dimensions have to measured and recorded in the planning system.
5. Pallet sizes and fill levels have to be established.
6. Safety stock and re-order intervals have to be known.
7. Sales forecasts have to be available in product units.
8. The requirements for storage environment of every component have to be known.

As a conclusion, academic research does not provide many models for long-term warehouse capacity planning in pallet spaces in a pharmaceutical company. However, the model provided in Battersby and Garnett (1993) is straightforward and simple to use. With this kind of simple model the question turns from tool availability to data availability and quality. Since the model uses sales forecasts and inventory management data as inputs, the data needed has to be well available for the planning to be effective and efficient. Therefore, as will be shown in chapters 4 and 5, the latest data has to be shared in-house and with suppliers and customers, when needed. This requires collaborative planning in the supply chain instead on consecutive forecasts from each company. Also, the integration between information systems is crucial since data pieces from different systems have to be compatible with each other.

3.8 Chapter summary

When creating value adding supply chains companies have to forecast and anticipate major trends that will affect their business on the long term. According to Hameri and Hintsa (2009), in the coming 10 to 20 years among the most important supply chain performance metrics are perfect order fulfillment and delivery performance. This clearly puts emphasis on reliable operations. Because pharmaceutical products are used to treat people, an inefficient or poorly functioning supply chain can lead to loss of human lives. This is partly the reason that the pharmaceutical companies were in the past ready to keep high inventories to ensure reliable service levels (Ehrhardt et al., 2012).

To become more efficient, pharmaceutical companies can concentrate on cost cutting, and this includes more accurate warehouse capacity forecasting in the long-term. Unfortunately, academic research has few tools to offer for this type of planning, but it provides data requirements for forecasts tools and processes. In the future, more advanced forecasting techniques may not be enough for companies to be cost-efficient. As flexibility is becoming increasingly important, and insufficient warehouse capacity should not be a bottleneck for other operations, simply trying to forecast more accurately is hardly enough. This implies that companies should become more flexible instead of trying to see the future and just plan and execute their operations accordingly. Embracing quick changes is the requirement for an effective future supply chain. Becoming more flexible, also regarding warehouse capacity, could provide both better service levels and improved cost-efficiency for the supply chain. This viewpoint, findings and views from other industries are discussed in chapters 4 and 5 and part 7.5.

4. Industry interviews

4.1 Warehouse capacity planning in the pharmaceutical industry

In the mother project, Felix Friemann conducted an interview series with 11 of the 20 largest pharmaceutical companies by revenue of the year 2012. According to the results of the interview series with the pharmaceutical companies, 27 % of the companies conduct warehouse capacity planning on a rough level with a five-year horizon, and 55 % do not conduct dedicated long-range warehouse capacity planning. About three in four companies had a central department for warehouse capacity planning. In other cases, sites did the planning individually, or the planning was unnecessary due to flexible contracts with 3PLs.

In the pharmaceutical companies doing long-term warehouse capacity planning the central planning would receive sales forecasts from the sales department and based on that information give out production plans and warehouse capacity plans. The systems used for long-term warehouse capacity planning included the company ERP and its extension modules, Excel and commercial supply chain or warehouse planning software. The planning was often done on global level.

As indicated in Figure 4 in appendix A, the forecasts for warehouse capacity in the pharmaceutical companies are on average deemed accurate for the next 2.5 years, with responses ranging from one to five years. The time needed to increase warehouse capacity ranged from six to 24 months with an average of 16 months. The time needed to increase warehouse capacity did not correlate with the level of warehouse capacity planning; companies with the longest lead times for warehouse capacity increases were not necessarily the ones doing long-term warehouse planning. This could be explained by the fact that a two-year capacity forecast can be made in sales and operations planning without the need for long-term projections.

The need for long-term warehouse capacity forecasting does not seem to be a global phenomenon in large pharmaceutical companies. Rather, it is company dependent and may sometimes be overcome with flexible contracts with 3PLs. Furthermore, the product portfolio may affect the need for long-term forecasting. For example, drugs and vaccines for rare diseases may face a more fluctuating demand, while other products have stable demand, which would decrease the need for forecasting long-term warehouse capacity. However, these viewpoints were not examined in the pharmaceutical interviews and therefore cannot be supported with its findings.

The need for forecasting the long-term needs of warehouse capacity in some pharmaceutical companies is evident, yet the proper tools do not seem to exist. Therefore, the search for applicable tools and processes in other industries was conducted.

4.2 The examined supply chains in the interviewed companies

The rest of the chapter presents the results from the interview series conducted for this thesis with the selected nine companies from the four different industries. First is presented what supply chain attributes are important for the interviewed companies and how outsourcing is used to increase operational efficiency. The findings provided insights for outsourcing and using collaboration in warehouse planning. Finally are presented four company-specific planning processes for long-term warehouse capacity, and future trends with their implications on long-term warehouse capacity forecasting are discussed.

All company-specific results are presented anonymously in Appendix A to preserve confidentiality. The quantitative results are presented per company in Appendix A and have been aggregated in chapter four into industry averages to show the general results and the differences between industries. The results are also compared against those of the interview series with the pharmaceutical companies to identify major differences and development areas for Nixoran.

Figure 5 in appendix A presents the simple four-stage model that was used to represent the part of the supply chain, on which the interview series concentrated. The stages were primary manufacturing, secondary manufacturing / assembly, packaging and distribution center. In Table 1 are presented the industry specific names for the four supply chain stages, the scope of which differed between industries. Depending on the company, the different stages would be outsourced to some extent. The stages only represent the operations of an interviewed company in the supply chain, leaving out suppliers and customers, unless they are carrying out some of the mentioned operations. The cosmetics industry had secondary manufacturing and packaging as one combined stage of operations.

Table 1: The industry specific naming of the different segments of the supply chain inside one company.

Industry	**Primary manufacturing**	**Secondary manufacturing**	**Packaging**	**Distribution center**
Automotive	Part manufacturing	Sub-system assembly	Final assembly	Distribution centers and dealerships
Cosmetics	Ingredient manufacturing	Final product manufacturing and packaging		Distribution centers
High-technology electronics	Part manufacturing	Final assembly	Packaging	Distribution centers or direct deliveries
Semiconductor	Wafer manufacturing	Wafer testing	Sawing and packaging	Distribution centers

In the semiconductor industry the manufacturing of the silicon discs containing the initial integrated circuits is called wafer manufacturing. The correct functioning of the circuits on single wafer is tested, after which the wafer is sawed into individual integrated circuits that are packed.

4.3 Rating of supply chain attributes

Every interviewed company evaluated the importance of five supply chain performance attributes: reliability, responsiveness, flexibility, cost management and asset management. The chosen attributes are used in the supply chain operations reference model (SCOR), which is a widely used model for describing, evaluating and enhancing supply chain operations. For more information on SCOR, see for example the Supply Chain Council web site (Supply Chain Council). The interviewed companies identified the importance of every attribute on a scale from four to zero, four being priority and zero being not important. Every attribute was graded independent of the other attributes.

The most important attribute was reliability, with cost management and responsiveness also being important. The least important attributes were flexibility and asset management. Figure 6 in appendix A presents the interview results, and industry specific aggregation is presented in Table 2. For comparison, the results from the pharmaceutical industry, provided by Felix Friemann, are also presented. In the pharmaceutical industry the most important supply chain attribute was reliability and the least important was asset management.

Table 2: The importance of the different SCOR supply chain attributes for different industries. Felix Friemann provided the results for the pharmaceutical industry.

Industry	**Most important attributes**	**Least important attributes**
Automotive	Reliability	Asset management
Cosmetics	Reliability	Asset management
High-technology	Reliability and asset management	Flexibility
Semiconductor	Reliability and cost management	Responsiveness, flexibility and asset management
Pharmaceutical	Reliability	Asset management

For all the interviewed industries, reliability was the most important supply chain attribute. For the semiconductor industry cost management was also important. For the high-technology industry asset management was also important, which was shown in the concentration on supply chain development and standardization to decrease cost pressure, which is discussed in part 7.5. The most important metrics for reliability were service level and on time deliveries in full, meaning the percentage of customer deliveries that were fulfilled completely according to customer order and on time. These attributes and metrics are the same as the supply chain trends identified in Hameri and Hintsa (2009).

For the automotive and cosmetics industries, asset management was the least important attribute. In the automotive industry one respondent mentioned supply chain operations to be only a means to fulfill the design requirements provided by research and development, providing a somewhat narrow view on the whole concept of supply chain. In the cosmetics industry asset management was not always measured. When measured, the used metric included capital tied up in inventories and annual capital expenditures.

In the high-technology industry, flexibility was the least important supply chain attribute, since quickly replacing large suppliers during force majeure situations can be impossible. Also, meeting customer needs and orders reliably was deemed more important than being able to quickly respond to market changes. In the semiconductor industry responsiveness, flexibility and asset management were seen as the least important supply chain attributes. Like in the high-technology industry, reliability was much more important.

4.4 The extent of outsourcing

As shown in Figure 7 in appendix A, in the interviewed companies primary manufacturing, secondary manufacturing and packaging are always carried out on global or regional level; a single site serves other sites in one or more geographical regions. The regions usually consist of continents or their combinations, for example EMEA (Europe, the Middle East and Africa). For all companies, the distribution centers operate either globally and locally or regionally and locally. Both centralized warehousing and close-to-customer distribution were used, depending on the market and product. The companies also expect their current focus of operations to stay roughly the same, although the balance between global and local reach may change, depending on markets and technological changes. For example, one respondent identified 3D-printing as a technology that could change the current distribution logic, since retailers could produce some finished goods at their own facilities on customer demand.

All companies had outsourced a portion of their operations. Company results are presented in Figure 8 in appendix A. In the automotive industry, the exact figures on the level of outsourcing were not available. However, the largest number of suppliers provided parts, which would suggest that primary manufacturing is the most outsourced stage in the automotive supply chain. In the cosmetics industry primary manufacturing and distribution were the most outsourced stages. The high-technology industry uses outsourcing most extensively, with one company concentrating on supply chain management and only having insourced about 50 % of secondary manufacturing. In the semiconductor industry, packaging was the most popular target for outsourcing, with distribution centers being also largely outsourced. In general, the in-house operations may be further outsourced in the future, but this was company dependent. In Table 3 are summarized the most popular outsourcing reasons and the outcomes that are reached for with the outsourcing decisions.

Two companies mentioned specifically that they own many facilities where the work force has been at least partly outsourced. One automotive company had outsourced the blue-collar workers in warehouses, and one cosmetics company had outsourced the pallet handling in distribution centers to a 3PL, but still carried out the picking and packaging of customer orders. The cosmetics company owned half of its distribution centers and was going to centralize distribution in the future.

Table 3: The main reasons for outsourcing and the expected outcomes of the outsourcing decisions.

Main reasons for outsourcing	**Number of responses**	**Outcomes to be reached**	**Examples**
Cost reduction targets	5	Decrease own operating costs by using a cost-competitive capacity supplier.	A 3PL provides cheaper warehouse operations due to its economies of scale.
Feasibility of investments	4	Gain more capacity although investing in new capacity is not feasible.	Buy manufacturing capacity from a contract manufacturer, who serves multiple manufacturers and has therefore high utilization rates.
Supplier expertise	4	Gain better performance by leveraging the capabilities and expertise of other companies in their respective fields.	A logistics provider has effective and efficient processes for warehousing and transportation.
Strategic decisions	2	Keep core-operations strictly in-house and prevent knowledge leaks.	Concentrate on product design and engineering and outsource manufacturing.
Higher need for flexibility	2	Be able to react quickly to demand changes and have always the correct amount of capacity available on a relatively short notice.	Use a 3PL for warehousing and have the option to adjust the leased warehouse space within months.
Decreasing own complexity	2	Let another company provide you with assembly services and take care of part storage.	Buy assembly services from a service provider to decrease the number of own SKUs.
Lowering the market risk	1	Enter markets where both high returns and high losses are possible.	Buy capacity from companies that have operations in the target markets.

The most prevalent reason for outsourcing was cost reductions. However, many companies emphasized that cost reduction is the final reason but not the only one. The costs of different alternatives are compared when other, contingent requirements, like product specifications, production process requirements and supplier reliability, are first fulfilled. Tightly linked to the cost aspect is also the feasibility of investment, which was with supplier expertise the second most popular reason for outsourcing.

4.5 Company-specific warehouse capacity planning processes and tools

Four of the nine interviewed companies had in place a process for warehouse capacity planning for at least a five-year time span. In appendix A Figures 9–12 present the outlines of these process models: participating functions, planning horizon, responsibility, data inputs, used tools and the output. The exact approaches of the four companies differed from one another in many areas. The responsibility for long-term warehouse capacity planning was usually on global level but one company conducted it also on regional level. Also, the used tools differed: three companies used their ERP-system, Excel and dedicated warehouse planning software, while one company did all the planning using Excel. In general, the more a company had outsourced its operations, the lower was the level of detail in warehouse capacity planning. This observation pertained also to the companies with shorter planning horizons and less complicated products. Therefore the most applicable planning processes and tools for Nixoran should be looked for in those companies that have own operations spanning from manufacturing to distribution with a multitude of different complex product variants. From this perspective, Models 2, 3 and 4 are the best alternatives. All the four models are presented in parts 4.5.1–4.5.4. A summary of the four models is presented in Table 4.

The company using Model 2 was the most satisfied one with its planning tools, naming no obvious problem points. In general, most of the interviewed companies were mainly satisfied with their warehouse planning process and tools, but also identified specific areas for improvement, as indicated by Figure 13 in appendix A.

Table 4: A summary of the four models for long-term warehouse capacity planning in other companies.

Model	**Number of participating functions**	**Planning horizon in years**	**Responsibility for data inputs**	**Number of used tools**	**Dedicated tools in use**
Model 1	3	5	Global and regional	1	No
Model 2	4	5–10	Local and regional	≥4	Yes
Model 3	4	6–13	Global, regional and local	≥4	Yes
Model 4	5	10	Global and regional	4	Yes

4.5.1 Long-term warehouse capacity planning – Model 1

The planning process presented in Model 1 takes as inputs the sales forecasts from the sales and marketing department and finished goods levels from the purchasing and planning department. The inputs are provided on a global and regional level in volumes for every product segment. From the input data the strategic planning department and logistics department derive global warehouse capacity needs in pallet spaces and goods volumes per storage type.

Model 1 shows that the pallet space needs can be forecast with the participation of only three business functions, although differences between companies may arise from the division of tasks between functions. Also, as the company using Model 1 has outsourced the handling of pallets to a 3PL, the planning process is quite light. The company using Model 1 only does the picking and packaging at its own distribution centers and the transportation of goods to customers is outsourced. The absence of completely insourced warehouse capacity management requires less input data and work for the planning process.

The company using Model 1 identified the lack of structure for the planning systems to be the largest problem with the current warehouse capacity planning. Using only Excel does not easily promote standardized planning procedures or data. On the other hand, the planning process was light and relatively easy to carry out due to not having multiple tools.

4.5.2 Long-term warehouse capacity planning – Model 2

In Model 2, the estimated warehouse capacity needs are based on sales forecasts, including product launches and ramp-downs, current warehouse capacity and manufacturing capacity. The information is provided on local level, meaning that every site provides their figures individually for the central planning. The existing warehouse capacity is given per storage type, for example pallet rack spaces. The sales forecasts are provided per product group also on regional level, meaning the geographical business areas, for example EMEA. Global capacity analysts, who are located at the largest sites, analyze the data on regional and global level. The result is a 5–10 year projection for the needed global warehouse capacity in pallet spaces or other storage units. The global capacity analysts use at least the ERP-system, two dedicated in-house developed tools and Excel to forecast the warehouse capacity needs. In Model 2, the company using it identified no problem areas, and the satisfaction with the current process was very high.

The company using Model 2 does not have as much variety in its final products as Nixoran; pharmaceutical products use a number of different and individual chemical compounds, while the products of the company using Model 2 need a lot less different raw materials. The storage requirements for raw materials and finished goods in the corresponding industry are also less stringent. These two facts may make the warehouse capacity planning easier, at least regarding raw materials. However, the biggest insights provided by Model 2 are that the structure of the planning process, data quality and the integration of the tools and data systems are basic requirements for successful warehouse capacity planning.

4.5.3 Long-term warehouse capacity planning – Model 3

The company using Model 3 was not able to verify the initial interview results, so mistakes in the description of the forecast model are possible. However, the interview was done face-to-face, which decreased the possibility of misinterpretation.

In Model 3 the internal logistics function forecasts the pallet space requirements on global level. Many functions are involved in the planning process, including infrastructure management. However, three parties can be named as the most crucial information providers in the scope of this thesis: product lines, volume planning and physical logistics. The individual product lines provide future manufacturing plans on product and site level. Volume planning gives sales forecasts on global level, and physical logistics gives the current warehouse capacity on global level. New product launches are taken into consideration in the information provided by the research and development function to the product lines. The IT (information technology) department is responsible for forecast tool support and development. The tools used in Model 3 include the ERP system, Excel and other planning software.

The biggest problem with the planning process, identified by the respondent, was the uneven level of data granularity. Final products use specific parts although warehouse capacity is planned for part families. This requires aggregation of the granular part level data before it is usable as raw data for the warehouse capacity analyses and forecasts.

4.5.4 Long-term warehouse capacity planning – Model 4

The company using Model 4 was not able to verify the initial interview results, so mistakes in the description of the forecast model are possible.

In Model 4, the central planning for every brand does the long-term planning for warehouse capacity on a 10 years' horizon. The result is warehouse capacity needs per country. Like in Model 3, a large number of parties are involved in the planning process, but in Model 4 four functions provide the most crucial information for central planning: sales, product research and design, supply chain management and financial departments. All the inputs are given on regional and global level. Sales function gives the sales forecast on product level. Product research and development provides the plans on future products on product level. Supply chain management gives the estimates on future material flows on country level, and financial departments provide cost parameters, like inventory costs and warehouse building costs. The IT department is responsible for forecast tool support and development. The tools used for the planning process in Model 4 include the company ERP system, an in-house developed WMS tool, a commercial distribution modeling tool and Excel.

With Model 4, the respondent identified the biggest problem to be the lacking global view on warehouse capacity. Currently the company can optimize country level warehouse capacity, but incorporating country borders crossing product movements requires new tools, which are already being developed.

4.6 Future trends identified by the interviewed companies

The importance of different future trends for the interviewed companies is presented in Figure 14 in appendix A. On industry level, all four industries identified increased cost pressure, having flexible capacities and end-user safety of products as the most important future trends. All three trends were evaluated as being either important or very important. The least important trend was product postponement. However, on industry level the results differed from one another. The most and least important trends for every industry are presented in Table 5. The results for the pharmaceutical industry are not presented in Table 5, because the pharmaceutical interviews concentrated on more industry specific trends. However, according to the interview series conducted by Felix Friemann within the mother project, in the pharmaceutical industry the most significant trend was growth at the emerging markets. Other important trends were cost pressure, personalized medicine, anti-counterfeit measures and the temperature control in manufacturing and warehousing facilities.

Table 5: The most important and least important trends for the four interviewed industries.

Industry	**Most important trends**	**Least important trends**	**Approaches for overcoming challenges**
Automotive	More individualized products	Postponement and product safety	Using simulation tools, adopting new warehousing systems and increasing outsourcing to make warehousing match the challenges.
Cosmetics	More individualized products and flexible capacities	Product safety	Re-design the supply chain, make forecasts that are more accurate and increase data usage in forecasting and modeling.
High-technology electronics	Cost pressure and product safety	Special warehousing and individualized products	Increase supplier integration, use standardized parts and processes and conduct supply chain modeling.
Semiconductor	Flexible capacities, cost pressure and product safety	Special warehousing and anti-counterfeit measures	Standardize manufacturing equipment and develop a leaner production system. Communicate with customers to align own capacity with demand.

In the automotive industry, more individualized products were seen as a strong trend due to the increasing variety of products, though it was not seen as a big challenge; the automotive companies expected that they would be able to develop their supply chains to accommodate the increasing complexity. The increasing product complexity will make warehousing more difficult, since the number of parts will grow, requiring the re-structuring of current warehouses and the warehouse network. Postponement and product safety were not seen as future trends since they are already implemented to a high degree and are a part of everyday operations and requirements.

The automotive companies had already implemented simulation tools to model the supply and distribution networks. This enables the optimization of warehousing locations and inventory levels, although a global view on warehousing is still missing. New warehousing systems are also implemented to accommodate the increasing number of product and part configurations. This, combined with the outsourcing of assembly operations, lets the car manufacturers use a larger variety of parts and finished goods and keep the complexity of their internal operations from increasing at the same rate.

The cosmetics companies ranked individualized products and flexible capacities as the most important future trends. New markets with individual demand characteristics and regulations will require a larger product variety. In addition, higher flexibility is required when the markets are more segmented, even to the level of individual consumers, which is the case for one of the cosmetics companies Like in the automotive industry, product safety was not seen as a future trend since in many countries and economic areas laws already regulate product safety. One respondent gave European Union and its chemical regulations as an example of the legal requirements for product safety. Some cosmetics companies aim to re-design their supply chain to increase flexibility and meet more individualized demand. Batch sizes may be decreased to increase flexibility and warehousing will be designed and carried out according to customer proximity, geographical limitations and demand patterns to combine the cost advantages of centralized warehousing and the responsiveness of being close to the customer.

In the high-tech electronics and the semiconductor industry, cost pressure and product safety were seen as the most important future trends. The respondents did not specify, if the safety requirements pertain to the physical safety of the end-customer or, for example, to data safety. Although this detail was not revealed, both industries could be expected to pay attention to both; electrical devices and semiconductors are used widely in everyday life and they often control mechanical systems, the malfunctioning of which could lead to the loss of human lives. For example, the failure of a control circuit in an automobile can lead to the driver losing control of the vehicle. Also, companies, societies and individuals use high-technology electronics to store private information, the loss of which can lead to social, political, financial and other problems.

Standardization of parts and final products and increased cooperation with suppliers were the most popular practices to cope with the cost pressure and manufacture safe products in the interviewed high-tech electronics and semiconductor companies. Standardized products and processes provide cost savings by decreasing the part variety and increase the product safety since exceptions and flaws in standardized products and processes are easier to identify. These approaches are also used to fulfill the need for higher flexibility, since modular processes can at their best be used to tailor the respective supply chain for every customer.

Special warehousing requirements and anti-counterfeit measures in general were not seen as future trends. In the automotive, high-technology and semiconductor industries the raw materials, semi-finished products and finished goods seldom require anything more than indoor warehousing. The measures for fighting against product counterfeits with supply chain safety improvements have also been implemented in at least some companies. For example, one company stated having a dedicated department for identifying possible counterfeit products. The company will then take action as suggested by the department. In the high-technology industry more individualized products was not seen as a trend; the companies are already offering customers tailored products and services using standardized parts and modular operations. In the semiconductor industry anti-counterfeit measures was not perceived as a future trend.

As a conclusion, all the interviewed industries perceive cost cutting as an important trend, but many find other areas, like the demand for more individualized products, more dominant. The relative importance of the different trends will obviously affect the warehouse planning and supply chain development processes of the companies. For example, focusing on cost cutting may require a company to centralize its warehousing, while the requirement for more individualized products would place the emphasis on increasing the flexibility of the supply chain and warehousing. Therefore, the trends in the different companies provide a direction for further benchmarking. Since cost pressure and individualized medicine were among the major trends in the pharmaceutical industry, all the other interviewed industries may have suitable approaches to offer. Regarding cost pressure, the most promising may be the high-technology and semiconductor industries, while for individualized products the attention should be turned to the automotive and cosmetics industries.

5. The improvement areas for Nixoran in long-term warehouse capacity planning

5.1 A classification for areas of improvement

This chapter presents the conclusions made from the interview results and provides recommendations for Nixoran to improve supply chain alignment and warehouse planning. These recommendations might be applicable also in other large research-based pharmaceutical companies that want to improve their forecasting of long-term warehouse capacity needs. The given suggestions provide answers to research question number 4: ”*How can the lessons from literature and other industries be used at Nixoran?*” regarding the contributions of other industries.

The interview results can be classified into five categories:

1. Improving supply chain characteristics
2. Tools used for warehouse capacity planning
3. Data management
4. System integration
5. Perceived future trends

Each of the five categories is discussed in the following parts and the main implications of the interview results are presented for each category.

5.1.1 Improving supply chain characteristics

The pharmaceutical companies and the companies in the other four industries agree that the most important supply chain metric is reliability and asset management is the least important characteristic. However, the pharmaceutical companies identified company strategy and supplier expertise as the main reasons for outsourcing, while the other industries’ main reasons for outsourcing were cost and asset management and supplier expertise. Retaining the level of reliability and good service levels can be contingent requirements that have to be fulfilled before any cost evaluation on outsourcing is done, as explicitly mentioned by one interviewed company. In general, the companies in the other industries did not explicitly identify the retaining or increasing of reliability as a reason for outsourcing. This raises the question, whether the rank of the supply chain attributes in companies is consistent. It is possible that companies perceive and communicate a different order of importance of the supply chain attributes than what they are actually following. This will lead to internal and external misalignments: different parts of the supply chain, even within one company, can be working towards different targets. This will decrease the efficiency and effectiveness in the supply chain, as not all, if any, operations are reaching the targets. As a conclusion, a company should consistently promote the chosen supply chain attributes in all operations, since the different metrics are partly antagonistic. Therefore, a company promoting its reliability should also make sure that all its operations and suppliers are reliable. This also requires reliability from warehousing instead of only low-cost operations.

The general results would imply that companies are willing to keep made commitments at the expense of asset optimization. Like the other industries, pharmaceutical companies likely see reliability as a valuable characteristic that has high importance when forming business partnerships.

In order to develop the reliability and other supply chain attributes, the pharmaceutical companies should learn from the high-technology and semiconductor industries how to improve performance in one area while keeping the performance in other areas at the achieved level. This logic can obviously be used in warehouse capacity planning, too. For example, the company can concentrate on improving data management while keeping the achieved accuracy of the modeling process at the current level. This may be difficult, since changing the data management processes could have initially a negative impact on the input data timeliness, quality and consistency. Therefore keeping the current performance level in one area while developing the other is not a trivial task.

5.1.2 Tools used for warehouse capacity forecasting

The company using Model 4 stated that a more global view is required to correctly model and optimize the global warehouse capacity. The company is currently developing and partly already using such a tool. This implies that the initial forecasting tool should be quite simple and not try to capture all the complexity of the warehousing network. Doing development in stages helps reach objectives and stabilize the achieved performance levels before moving on. Also, like the company using Model 2, the company using Model 4 uses in-house developed software as part of their tool kit. This hints that company-specific needs may well require the customization of a commercial tool, if not the development of a fully customized tool.

5.1.3 Data management

Since the computation of warehouse capacity needs can be relatively simple, the bigger problem is often the data availability and data management. Having the correct data pieces available in the right format and level of accuracy for the right persons is not a trivial task.

The Model 1 for warehouse capacity planning in part 4.5.1 shows that the data consistency is a crucial factor in modeling warehouse capacity needs. In Model 1 both departments providing the data inputs give them in product volumes. One interviewed cosmetics company has some inputs in product volumes and some in financial figures. Although the conversion of product volumes into financial figures and vice versa may be simple, the necessary conversion factors have to be easily available. The need for separate conversion increases the effort for data management unnecessarily and is prone to errors when done far away from the original data source. Converting the inputs before giving them forward in the forecast process may save time and effort and especially decrease the possibility of errors.

For Nixoran the major difficulty in long-term warehouse capacity planning is the lack of input data. Products early in the research pipeline are missing specific package dimensions, bills of materials and the other data needed for accurate warehouse capacity planning. Therefore, the long-term forecasts for these products are rough estimates at best.

For the products that are on the market or about to be launched, the input data at Nixoran is better available. The question is then, if the input data is reliable. The largest uncertainty is caused by sales forecasts. As indicated by Osborne and Nault (2012), data accuracy can be enhanced via data validation rules and real-time information sharing. The interviewed companies also mentioned these methods as ways of decreasing forecast uncertainty.

The data management can be either centralized of decentralized, and the Models 1-4 used one of either approaches successfully. With Model 3, the respondent was not able to confirm the details of the planning process, but the received information shows that the necessary data can be centrally managed to a large extent. For example, the information on existing warehouse capacity is received from the corporate level function of physical logistics, instead of being collected form individual sites. On the other hand, Model 2 shows that the input data can be managed and provided locally. This requires seamless system integration, so that the local data can be easily aggregated and used for global analysis. The centralization of data inputs in Model 4 shows again, like in Model 3, that centralized functions can manage the input data, instead of local sites providing the data directly for the warehouse capacity planning.

Data management is currently probably the most important problem area for Nixoran in developing a model and process for long-term warehouse capacity planning. The input data can be managed locally, but the data inputs provided for central planning have to be consistent company wide and the data have to be validated and sanitized before being given out. The data also have to be consistent, using the same units of measurement and level of granularity.

5.1.4 System integration

The number of used tools in the presented planning models varied from one to at least four different tools used within one company. Even with many different tools, the planning as a whole can work extremely well. This requires good system integration for easy access, sharing and usage of data. Especially with tailored tools, system integration becomes very important; if the special tools are not compatible with the other systems, they offer little value.

Model 2 for long-term warehouse capacity planning shows the importance of system integration for successful warehouse capacity planning, but also the advantages of using multiple systems. When data can be moved easily between different planning tools and used effectively, individual tools can be lighter and be used for specific planning purposes. This approach also loads the company ERP less, when not all planning processes are carried in it. Also, the dependence on one software supplier decreases, but on the other hand, the workload for system integration increases, and the amount of required in-house expertise becomes higher.

5.1.5 Perceived future trends

In the interviewed industries, excluding the pharmaceutical industry, cost pressure, flexible capacities and product safety were the most important trends. Special warehousing and anti-counterfeit measures were less important. However, in the pharmaceutical industry the most significant trend was growth at the emerging markets, as indicated by the interview results received from Felix Friemann. Other important trends for the pharmaceutical companies were cost pressure, personalized medicine, anti-counterfeit measures and the temperature control in manufacturing and warehousing facilities. The pharmaceutical industry perceived cost pressure as an important trend like did the other interviewed industries. The importance of costs did not undermine the importance of other trends. Therefore, it could be expected that companies strive to improve their operations efficiently and adopt new technologies to produce better products with less expenses and material usage. This trend may also be reflected in warehousing: companies should provide at least the current service levels with smaller inventories, higher inventory turn-over rates and less spoiled goods.

Since increasing cost pressure was only one of the many trends, seeing it dominate the focus of future improvements may seem contradictory. However, since costs can be decreased in a straightforward manner by laying people off, as opposed to improving work flows and processes, cost management may become the main focus. Yet, the concentration on the other trends could also provide cost reductions as side benefits. Increasing flexibility by creating modular processes and supply chains can reduce required capacity while improving performance. This view should be considered also in warehousing operations, where the purpose is to ensure a reliable and possibly flexible product supply. Of the interviewed companies, one in cosmetics can be given as an example of one with a need for higher flexibility. Because the company serves consumers directly, its markets are extremely segmented; individual consumers seldom have identical demand patterns and drivers. Although the aggregate demand in a given geographical area may be quite constant and predictable, the business logic requires high flexibility, so that the needs of individual consumers can be met reliably and cost-efficiently. At the same time, the increasing cost pressure calls for more centralized warehousing and global warehouse management to gain the benefits of large-scale operations.

One major trend was the increase in product complexity, which also makes warehousing more difficult and requires outsourcing if own complexity in warehousing is to be reduced. Having suppliers deliver sub-assemblies and intermediate products instead of parts lowers the number of SKUs. However, this requires new skills in contracting and supplier management to ensure product quality and the timeliness and perfect order fulfillment.

5.2 Chapter summary of the interview results and recommendations for Nixoran

The purpose of the interview series was to answer research questions number 3: "*What kind of process models and tools are used in other manufacturing industries, apart from the pharmaceutical industry, for long-term warehouse capacity planning?*" and 4: "*How can the lessons from literature and other industries be used at Nixoran?*" The findings are applicable also in other research-based pharmaceutical companies that are similar to those interviewed by Felix Friemann within the mother project..

In the following are summarized the interview results and the recommendations based on the results. Table 6 lists the identified common characteristics of a good and bad process for warehouse capacity planning. The results are based on the advantages and problem points of the company-specific planning processes mentioned by all nine interviewees and on the characteristics of Models 1–4.

Table 6: The properties of a good and an inferior process for warehouse capacity planning.

A good planning process	**An inferior planning process**
Is as simple as possible and uses dedicated planning tools when necessary.	Uses little automation in data aggregation and manipulation.
Uses all the tools that are needed, not only those that are easily available.	Requires manual collection of input data.
The tools and systems are fully integrated with each other.	Initial data has to be worked on before it can be used as raw data for warehouse planning.
Uses a centralized database for most, if not all input data.	The necessary data are available only in many different databases, not centrally.
The input data is complete, consistent, accurate and granular enough.	The needed data are not consistent or do not have the desired level of granularity.
The input data is easily accessible for the planners and easy to update.	The input data has no owner who is responsible for data quality.
Has clearly defined tasks and responsibilities for every party of the planning process.	The planning process is not formalized.

The problem of modeling long-range warehouse capacity needs at Nixoran is three-fold. First, currently Nixoran does not have a process or a dedicated tool for continuous modeling of long-term warehouse capacity needs, covering a 3 to 10 years' timeframe. Second, the data needed for modeling may not be available at all, or it may be scattered in the organization without any aggregation. Third, the modeling process has to be integrated with other business planning processes. Lastly, the importance of improved forecasting should not overshadow other possible approaches. Instead of improving the forecast process and accuracy, Nixoran could and should develop the flexibility of their warehousing operations. For this, the following areas should be improved:

1. Collaboration in demand and supply planning with customers and suppliers should be increased.
2. Data received from the primary source should be shared to decrease cumulative forecast errors.
3. Goals and incentives have to be aligned supply chain wide.
4. Warehousing operations should be made modular to increase flexibility.
5. Outsourcing should be seen as a way to establish partnerships and acquire new expertise instead of simple cost cutting.

The interview findings support the conclusions made in Hameri and Hintsa (2009) on the importance of supply chain reliability in the future. Since all the interview respondents emphasized this aspect, its importance seems to have a global reach over all industries. Therefore reliability cannot be overlooked in the pharmaceutical industry, even while other supply chain attributes are improved.

6. Tool concept development and proposal

6.1 Three concepts for modeling long-term warehouse capacity needs

This part evaluates the three developed model concepts for long-term warehouse capacity planning. The concepts were compared against the literature review results from chapter 3 and the interview results from chapters 4 and 5 to rank the concepts and give recommendations for further tool development and testing. The tool concepts were developed in the mother project and their initial feasibility was tested in this thesis with data from one Nixoran site, referred to as Site A. The question was, whether Site A can currently provide all the required data on the required level of granularity and consistency. Special attention in the concept evaluation was paid to potential tool accuracy and complexity, data management and integration of planning systems, which are among the most important aspects according to the interview results.

The three initially developed modeling concepts were Clustering, Bottom-up and Historical scaling. The Clustering approach scales the aggregate pallet space needs directly with sales data and sales forecasts. The Bottom-up approach calculates the pallet space needs based on sales forecast, bill of materials, pallet size, safety stock and the number of yearly orders. The Historical scaling approach simplifies the Bottom-up approach and being less labor-intensive with almost the same expected level of accuracy. Clustering uses product clusters to get a rough approximation on the future needs for pallet spaces, while the Bottom-up approach is very data intensive and tries to capture more input data and provide a very granular view on the warehouse capacity needs. Historical scaling lies between the two. This thesis concentrated on the evaluation of the Bottom-up and Historical scaling approaches, while Clustering was evaluated in the mother project. The results of the Clustering approach are presented to compare it against the other two concepts.

6.2 The Clustering approach

The Clustering approach clusters product names and production phases into groups where group members have similar bills of materials and pallet space requirements per one final product. In this way the total pallet space requirements can be scaled per cluster when the sales forecasts for that cluster are known. In the initial concept, the products were divided into six groups according to production technology and production phase. Among the different production technologies were tablets and vials. Three different production technologies and two production phases were initially used to cluster the product names into six groups. Between the groups, the average pallet space requirements per 100’000 units of produced goods varied, but in two groups the in-group variance was small. Table 7 presents the variance of the average number of pallets needed per 100’000 units of finished products for the six sample clusters. For production technologies B and C the clustering had to be taken even further; a more granular clustering provided the same level of in-group variance that was reached with technology A , but the number of clusters increased over twofold.

Table 7: The standard deviations from average pallet requirements for the sample clusters. Analysis performed in cooperation with Felix Friemann.

	Technology A	**Technology B**	**Technology C**
Production phase A	0 %	27 %	65 %
Production phase B	6 %	43 %	41 %

The data inputs required for the clustering are make-up level bills of materials, pallet size per component, temperature requirements and the production technology used for every final product. From these data, the average number of required pallet spaces per 100’000 units of finished goods is calculated for every cluster.

To forecast future pallet space needs the annual sales forecasts in product units are aggregated separately for all clusters. Then the number of pallets of materials needed for 100’000 units produced goods is multiplied with the sales forecast to get the annual pallet space requirements per storage type. To get an average daily inventory level, the annual figure is divided by 365. This assumes that the inventory levels are stable.

The Clustering approach does not only calculate the pallet space needs for existing products but can also be used for products in the research pipeline, as long as they can be placed into one of the clusters and provided with a sales forecast. After the initial work, the clustering approach is quite straightforward and fast to use, since it uses averages for larger product groups. The product clusters have to be updated less often, and only the sales forecasts require more frequent updating.

The accuracy of the Clustering approach depends on the successful clustering of the product names. In the future, more granular clustering may be required, especially if new product technologies emerge. Also, the clusters may have to be reviewed when new products are launched or old ones discontinued to accommodate possible changes in the average pallet space requirements. Although a detailed clustering increases the accuracy of the results, it also increases the workload. Thus, more detailed clustering is not always desirable since it mitigates the benefit of the Clustering approach against the other concepts, namely the use of averages for larger product groups. For product clusters of one product name, the Clustering approach converges with the Bottom-up approach, which is presented in part 6.4.

6.3 Advantages and weaknesses of using Clustering at site A

The benefits of the clustering approach are that once established, it is simple to use, is less data intensive than the other two concepts and takes into account the future products. At site A, the use of the Clustering approach is not strictly possible since all the required data is not available. The missing data are the product name level bills of materials that would also contain the proportions of component variants used. However, using historical inventory data can alleviate this deficiency; the proportions can be received implicitly by using past inventory levels. Since the inventory levels are based on demand forecasts, the inventory levels reflect the demand. The assumption behind this approach is the stability of demand, so that individual inventory reports can be stated to represent the average inventory levels. This approach and its validity are further analyzed and discussed in part 6.6 where the Historical scaling approach is presented.

The main weaknesses of the Clustering approach are the required amount of data in setting up the clusters and the limited accuracy. The amount of data and the work required for setting up the clusters is roughly the same as for the Bottom-up approach, which is likely to provide superior accuracy. The clusters are also prone to large changes in the product portfolio, since a cluster that is in use is based on a past product portfolio. Thus, large deviations from this portfolio may lead to large errors in forecasting future pallet space requirements, especially if the new products do not fit well under the existing clusters. However, since the product pipeline is long and only few products make it to the market, the clusters may stay stable for several years. This assumption has to be tested with history data to see, how much the product portfolio changes. Also, the possible changes in inventory policies have to be taken into account. Pallet sizes can be expected to stay the same, since they are dependent on the physical inventory system, the changing of which requires long-term investments.

6.4 The Bottom-up approach

One Nixoran site is using formula (7) to calculate the need for pallet spaces in temperature-controlled environment and room temperature. Formula (7) resembles formulae (2) and (5); it aggregates annual demand and averages it over one year, taking explicitly into account the safety stock and the number of annual orders. By assuming a constant demand, formula (7) gives the average safety stock added with half of the re-order quantity as the required pallet space capacity. This assumes that the inventory is below the safety stock level when an order arrives so that it can be accommodated in the inventory.

Formula (7) gives pallet spaces for a specific component type per make-up in the chosen storage temperature. The result is rounded up to the nearest integer to get the number of pallets. This result is multiplied with the number of make-ups to get the total pallet space needs for the component type. The storage temperature has to be known and is not part of the formula. Formula (7) was adopted for the bottom-up approach to see, what data are needed for the calculations and how well they are available at Site A. If the needed data are well available at other sites as well, the approach could be generalized and used globally to model the company wide needs for long-term warehouse capacity. The formula for the bottom-up approach is:

$$W_p = \frac{V_u G H}{I K} * \left(\frac{Q}{12} + \frac{1}{2P}\right) \tag{7}$$

where

W_p	is the number of pallet spaces needed for a given component in a given temperature per make-up.
V_u	is the annual demand forecast for a product name in units.
G	is the amount of component units used for one final product.
H	is the percentage of final products using a specific component type in one component family, for example the percentage of one etiquette type used in final products among three different etiquette types.
I	is the number of different make-ups for the chosen component type.
K	is the number of component units per pallet.
Q	is the safety stock in months.
P	is the number of re-orders to warehouse per year. $Re = \frac{1}{P}$ in formula (2).

The data needed for formula (7) can be extracted mostly from Nixoran's current databases. In Table 8 are listed the data needs for formula (7), the sources, the level of data accuracy and the level of centralization. The major problem with data collection and management is currently the lack of central ERP data management. Each site has its own ERP system, and although they are from the same software supplier, they are not fully integrated. Also, some sites have WMS data in their ERP while others do not, and the ERP and WMS have not necessarily been integrated for direct data exchange. By managing the required data according to the recommendations given in part 5.1.3 the data are better available and more consistent.

Table 8: The current location and quality of the required data inputs for the Bottom-up approach and formula (7).

Input data	**Availability at Site B**	**Level of accuracy**	**Level of centralization**
V_u	Long-range planning	Product name	Global sales planning
G	ERP, BoM	Per component type	Site level ERP
H	ERP	Per component type	Site level ERP
I	ERP	Per component type	Site level ERP
K	WMS	Per component type	Local warehouses
Q	WMS	Per component type	Local warehouses
P	WMS	Per component type	Local warehouses

For formula (7), the annual demand forecast for the product names and bill of materials data are used to calculate the individual component requirements. The aggregate component requirements are broken down into the level of component types, for example Label A, Label B and Label C, for a given final product. Finally, the number of make-ups for every component type has to be established. The relative proportions of sales of different make-ups, H in formula (7), can be calculated from historical sales data at Site A. Otherwise this information is not currently available. This means that also the Bottom-up approach may have to rely on past information on the relative sales between make-ups. Otherwise, the Bottom-up approach assumes equal sales for all make-ups of one product name.

The safety stock in months and the number of annual re-orders is taken as given from warehouse management data, since they are already established. If need be, they can be re-calculated from inventory data. Since the daily inventory levels are not tracked, getting reliable results using common analytic formulae is currently difficult. Therefore the inventory policies will be taken as given from Site A.

The number of annual re-orders is the total annual demand divided by re-order quantity, which is now taken as given. To calculate the safety stock using the formulae in Axsäter (2006, p. 88-95), the required input data are average demand and its variance, inventory replenishment lead-time, re-order quantity and the desired service level with its definition. The average demand and its variance can be calculated from changes in inventory levels when inventory levels and the timing and size of outgoing shipments are known. The safety stock can be then calculated using formulae (5.39) and (5.47) from Axsäter, if the demand is normally distributed. The distribution can be verified with statistical testing, for example, see Mellin (2008, p. 67-69). For other distributions, other formulae should be used.

In Axsäter (2006), the formulae used to calculate the safety stock assume a continuous review inventory policy where a re-order is sent out as soon as the inventory level is just below the re-order point. If the inventory level gets well below the re-order point, the results may no longer be valid since it is assumed that the inventory level is equal to the re-order point at the time the re-order is made. Therefore, the inventory review policy at Nixoran Site A may limit the usability of the formulae.

6.5 Advantages and weaknesses of using the Bottom-up concept at Site A

Because the Bottom-up approach gives the material and warehouse capacity needs for every single component based on product name sales forecasts and bill of materials data, the results can be deemed quite accurate; the usage of every single component per one finished product is independently derived from the bill of materials, and the pallet utilization and size are explicitly accounted for. The Bottom-up approach may assume equal sales for all the make-ups of one product name, which may not be the case. However, this does not necessarily make the results too inaccurate since different make-ups take up roughly the same amount of space. This means that even if one make-up dominates the component usage for one product name, it still takes the same amount of pallet space as any other make-up. This approach yields errors when the pallet utilization for less used make-ups is near 100 % and the predicted additional volumes cannot be accommodated on the existing pallets, while in reality the volume increases for the less used make-ups would fit on the existing pallets.

The potential accuracy of formula (7) requires very detailed data inputs and the uncertainties in these data inputs can make the result unreliable, if not unusable. Thus, the approach is potentially accurate due to incorporating detailed demand and warehouse data, but deficiencies in data quality can severely hamper the quality of the results. This was also the case with Site A: accurate pallet sizes are not currently available so the increased workload needed for the Bottom-up approach will not currently pay off. An estimate for the pallet sizes can be calculated from inventory reports, but it increases the workload, since daily inventory reports have to be exported manually from the WMS. For a rough estimate, end-of-the-month inventory reports were used to calculate the average pallet sizes. The inventory data contained the number of components per pallet for all the pallets in the inventory. These figures were averaged for every component over the last 19 months using the end-of-the-month figures.

The Bottom-up approach does not require knowing the relative distribution of demand for one product name between different make-ups. This information is not even directly available at Site A, but would have to be calculated from make-up level sales reports, increasing the workload. Also, the relative distribution of different component types used has to be calculated from historical sales data. This requires dividing the make-up level sales for the different BoM variants that use different component types. The bills of materials may differ between make-ups even so, that the only difference is the language printed on labels; individual make-ups can use unique component types, like some added packaging. Lastly, different pack sizes can have very different bills of materials since, for example, the usage of packaging material does not necessarily correlate linearly with the number of product units in a package. Consequently, getting the international name level demand granulated to the make-up level is not a straightforward task, but fortunately also not a necessary one. Still, the error caused by omitting this step in regular calculations has to be verified, if the Bottom-up approach is to be used.

The safety stock and re-order interval are taken as given and thus their calculation is not a problem. The largest problem is that the data extracted from different systems is not completely consistent. For example, the same product name could be written with slight variations, which makes data aggregation more difficult, unreliable and difficult to automate. Although the standardized number codes for product names can be used to partially overcome this problem, the numbers are not always used in a given data set; rather the numbers and names have to be linked separately. This increases the risk of error. The lack of links between data pieces also makes the granulating of product name level demand more unreliable and labor-intensive.

The deficiencies in current data management make the implementation of the Bottom-up approach at Site A currently very labor-intensive. The BoM data at Site A is difficult to link to historical sales data and sales forecasts and may require a large amount of manual labor, meaning the copying of tens of thousands of data entries.

6.6 The Historical scaling approach

The Historical scaling approach aims to retain the accuracy of the Bottom-up approach while making the calculations simpler and reducing the data requirements. The principle behind the concept is to create a base line for warehouse capacity needs by averaging history inventory data and then scale the future capacity requirements from this baseline. The data requirements for the Historical scaling approach are presented in Table 9.

Table 9: The data requirements for the Historical scaling approach.

Data	**Data granularity**	**Unit of measurement**	**Data location**
Global inventory report for base year	End-of-the-month inventory levels per material number	Units	ERP master data
Average pallet size	Material number level	Units per pallet	Site WMS
Temperature requirements	Product name level	Dimensionless	ERP master data
Sales data for base year	Make-up level	Units	ERP
Sales forecasts	Product name level	Units	Long-range planning system

Historical scaling uses the following steps to give an estimate on the pallet space requirements:

1. The base year's end-of-the-month inventory figures are summed respectively for all material numbers in the global inventory report.
2. The sums of the end-of-month-figures are respectively divided with the average pallet sizes to get the number of pallets.
3. The number of pallets for every material number is ear marked to temperature-controlled or room temperature storage according to the temperature requirements.
4. The sales data of the base year is aggregated from make-up level to product name level.
5. For every material number, the number of pallets is divided with the base year sales of the corresponding product name and multiplied with the sales forecast of the chosen year for the same product name.
6. The individually scaled pallet space figures for the two temperature zones are aggregated separately.
7. The aggregate figures are divided with the number of months used in the calculations to get a daily inventory average.
8. The result is an estimate on the average pallet space requirements for temperature-controlled and ambient storage.

The formula for Historical scaling is:

$$W_p^T = \frac{\sum_{j=1}^{m}\left(\sum_{i=1}^{n}\left(\frac{\sum_{t=1}^{k} C_{ti}}{K_C}\right) * \frac{V_j}{S_j}\right)}{k} \tag{8}$$

where

W_p^T is the aggregate number of pallet spaces needed for the analyzed storage conditions *T*.

C_{ti} is the inventory level of the ith material number at the end of the tth month during the base year.

K_C is the pallet size for material number C_{ti}.

V_j is the sales forecast for the jth product name.

S_j is the sales of the jth product name during the base year.

k is the number of months used for averaging.

n is the number of material numbers for a product name.

m is the number of product names.

Formula (8) gives the average requirements for pallet spaces in temperature-controlled and ambient conditions. If the summation over product names is not carried through, the results can be presented per product name. Also, if the summation over product names is omitted and the summation over the number of material numbers is omitted, the results can be summed over material type. The different material types are active ingredients, finished goods, packaging materials, semi-finished products and raw materials. The Historical scaling approach is based on the following assumptions and simplifications:

1. The number of pallet spaces during the base year is sufficient to meet the service level requirements during the base year.
2. The service level requirements will not change in the future.
3. The end-of-the-month inventory figures represent daily averages.
4. The daily inventory levels are stable.
5. Of all materials, only finished goods, raw materials and semi-finished products may require temperature-controlled storage.
6. The proportional demand of different make-ups of one product name will stay the same in the future.

The service level targets and the achieved service levels in 2012 were not available for Site A. Therefore the validity of the first assumption for Historical scaling could not be verified.

In the Historical scaling approach, inventory policies are not explicitly considered. This means that the calculated pallet space requirements are expected to meet a stable demand. The bill of materials is also not considered explicitly, rather implicitly via the inventory levels of the different material numbers, which classify the components at the make-up level.

The assumption of a constant demand may be justified with history data. To prove that the assumption holds, two further assumptions have to be proved. First, the used end-of-the-month figures are stable when compared against each other and second, the end-of-the month figures are representative of daily averages.

The consistency of the end-of-the-month figures was tested using inventory reports from Site A**.** The reports contained end-of-the-month inventory levels from years 2011 and 2012: the pallet space information for total temperature-controlled capacity and ambient capacity. The reports also contained the room temperature capacity for finished goods and room temperature capacity for packaging materials. From this data was calculated the averages for pallet spaces and their standard deviations. The standard deviations for the pallet space figures were calculated in two ways. First, the standard deviation was calculated from the straight figures for 2011 and 2012. After this, the end-of-the-month figures for 2011 and 2012 were compared against each other to get an average annual change in the number of pallet spaces, while taking into accord possible monthly variation. After this, the pallet space figures for 2012 were divided with the average rate of change to get a two-year data set without the effect of demand changes on the number of pallets in the inventory. From these data, the standard deviation was calculated again. The conclusion was that the end-of-the-month figures for aggregate pallet spaces are quite stable and from that perspective the inventory levels and demand are stable. Table 10 presents the standard deviations calculated from the inventory data.

Table 10: The standard deviations of average number of pallet spaces for selected goods in 2011 and 2012.

	Number of pallets in temperature-controlled environment	**Number of pallets in ambient temperature**	**Number of pallets for finished goods in ambient temperature**	**Number of pallets for packaging materials in ambient temperature**
Standard deviation from average	9.3 %	8.1 %	10.8 %	5.8 %
Standard deviation from average without demand changes	6.4 %	3.5 %	6.9 %	4.0 %

Although the analyzed inventory reports from Site A leave out the more granulated level of temperature-controlled capacity for finished goods, raw materials and semi-finished products, the results give a reasonably accurate view on the stability of the inventory levels. The temperature-controlled capacity is roughly 25–30 % of the total capacity at Site A, the majority being thus room temperature capacity. Formula (9), which was used to calculate the average pallet space levels, is the formula for arithmetic average (for example, see Mellin (2008)):

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{9}$$

where

$\bar{x}$ is the arithmetic average.

n is the sample size.

x_i is the ith member of the sample.

Formula (10) for sample standard deviation (for example, see Mellin (2008)) was used to calculate the standard deviations of the end-of-the-month inventory levels in Table 10, since the used data was assumed to represent a larger population:

$$s_x = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{10}$$

where

s_x is the sample‘s standard deviation.
n is the sample size.
x_i is the i^{th} member of the sample.
$\bar{x}$ is the arithmetic average.

To show that the single end-of-the-month figures are representative for the average daily pallet space requirements, the inventory movements have to be analyzed. These data were not available for this thesis but the assumption has to be validated in further testing.

6.7 Advantages and weaknesses of using Historical scaling at Site A

The main advantages of the Historical scaling approach are its potentially good accuracy and moderate workload. Creating the first tool version of the Historical scaling approach for Site A required significantly less work than the other approaches would have and the required data were available, although not initially fit for analysis. However, linking the data pieces together was possible and could be partly automated. The first version of the forecast tool and its evaluation was done as part of this thesis using Excel.

The main weakness of Historical scaling is its complete disregard for the future product portfolio. Since the concept is based on historical material usage, it does not lend itself for modeling the pallet space requirements of future products with no history data. Therefore, Historical scaling requires support from another tool for getting initial results for future products before they can be incorporated into Historical scaling calculations.

While assumptions 3–6 behind the Historical scaling are reasonable and the validity of assumptions 3 and 4 was partially proven, the situation may change in the future. Consequently, the stability of the inventory levels has to be monitored to verify that Historical scaling is still a valid concept. Also, the proportions of different make-ups of all sales have to be measured and accounted for. However, this can be done implicitly by using new warehouse data, where the inventory levels already reflect the inventory policies, which on their turn are based on demand information. Thus, the most important variables to measure are the stability of demand and inventory levels.

The reliability of the input data for Historical scaling is otherwise good, but the average pallet size is still a question. Since the average pallet size is currently calculated from static inventory reports, like for the Bottom-up approach, and the information is not available on all products, it causes a significant uncertainty. For the products without the data on average pallet size, a maximum pallet size is used, but for some products even those data are unavailable. Currently the number of those data entries in the global inventory report, that lack any pallet size data, is about 19 % for Site A. The temperature requirements are only given for product names, not material numbers, so it could be argued that the requirements of specific material numbers and components cannot be estimated. However, it is reasonable to expect that packaging materials do not require cooling, since they are seldom sensitive to higher temperatures.

The current deficiencies in data management and system integration at Site A also present their own problems for the usage of Historical scaling. The usage of product names is not currently consistent as there can be differences in the spelling of the names. In data aggregation this can be mostly overcome by using the standardized number codes for product names, but even these codes are not used in all data inputs, which requires yet other data tables to bridge the gaps and link all the necessary data inputs with each other.

The Historical scaling approach was partially tested with history data to calculate warehouse capacity needs in 2012. The results were compared against actual figures received from Site A warehouse management system. Due to the lack of some input data, the results were not conclusive, but they showed that Historical scaling may prove itself as a good tool for long-term pallet space calculations.

6.8 Chapter summary

In Table 11 are ranked the attributes of the three different tool concepts based on the results from the pilots done with Site A data. The metrics are based on the requirements received from Nixoran as well as on the results from the literature review and the interview series. The tool attributes are evaluated on a scale of 1–4, where 1 means low, 2 moderate, 3 high and 4 very high. The three approaches are evaluated relative to each other, not on any objective scale. The ultimate qualifier is the sum of all the positive attributes divided with the sum of the negative attributes. The positive attributes give a concept an advantage against the others while the negative attributes cause a disadvantage. The negative attributes and their values are italicized in Table 11. It should be noted that the result should not be evaluated with the original scale of 1–4; rather the ratios of results for the different concepts should be compared against each other. The comparison will tell, how sensitive the results are to changes in the estimates for the attribute values and if the results are reliable in that respect.

Table 11: The comparison of the three concepts for modeling warehouse capacity requirements.

Attribute	**Clustering approach**	**Historical scaling approach**	**Bottom-up approach**
The tool logic is easy to understand	4	4	3
Potential accuracy	2	3	4
Future orientation	2	1	3
Reliability of results for current portfolio	2	3	3
Workload needed to implement	*3*	*2*	*4*
Everyday workload	*1*	*1*	*2*
The amount of required input data	*4*	*2*	*4*
Required granularity of the input data	*3*	*2*	*4*
Ratio of the sums of the attribute values (efficiency ratio)	$\frac{10}{11} = 0.91$	$\frac{11}{7} = 1.57$	$\frac{13}{14} = 0.93$

Table 11 suggests that Historical scaling is the best concept of the three, providing the best potential accuracy, reliability and simplicity for the least amount of work. The major drawback of the concept is the lack of future orientation in the pallet space calculations. The Clustering and Bottom-up approach offer the same amount of reliability and accuracy per workload; the Bottom-up approach likely offers higher accuracy and reliability but with a significantly higher workload.

In order for the Bottom-up approach to reach the efficiency ratio of Historical scaling, the sum of the negative attributes for Historical scaling would have to increase by over 60 % or the sum of the negative attributes for the Bottom-up approach would have to decrease by over 30 %. The same applies when comparing the Clustering approach against Historical scaling. Similarly, the sum of the positive attributes for Historical scaling would have to be almost 40 % lower for the other two approaches to have the same efficiency ratio.

While the initial concept testing was conducted only for the Clustering and the Historical scaling approaches, only their relative accuracy against each other was evaluated. Still, because the accuracy of the Bottom-up approach can be expected to be superior, this was taken into account in evaluating the relative performance of the three concepts. The required workload was evaluated to some extent for all concepts, again more thoroughly for the Clustering and Historical scaling approaches. However, as the input data from Site A could not with the same level of effort be used to try out the Bottom-up approach, it became evident that implementing the concept at Site A requires more work than the other two approaches. Based on these tests and the wide margin of error in the ranking of the concept attributes, the Historical scaling approach seems to be currently the most promising one. However, since the testing was only conducted with Site A data, and the concepts were not tested thoroughly, the definite results will only be available, when additional pilots are carried out with other sites. That task, however, is outside the scope of this thesis.

The lack of future orientation in the Historical scaling approach has to be complemented with another concept. One way to do this is to use the global inventory report for the Clustering approach to calculate a base level for the different clusters. This supplementation does not increase the workload significantly, since the data required is the same as used for Historical scaling.

A major problem for implementing either the Historical scaling or Bottom-up approach globally is the possible inconsistencies in data formats. To make the accommodation and standardization of differing data formats from different sites as smooth as possible, it is wise to have the input data collection and analysis separated. This means that the sites will provide their input data in standardized formats into one single database, and the data will be separately imported to the warehouse capacity planning tool. Since system integration is important for successful planning, the tool can and probably should be an integral part of the database, but individual sites would not use the actual tool, rather they would only provide the input data. This idea is elaborated in Figure 3. First, the individual sites provide the required input data into a central database. Second, the central planning calculates the global long-term warehouse capacity needs and finally the results are used in strategic decision-making. The dashed lines in Figure 3 represent how the individual sites are not in direct contact with planning tool, yet the planning tool is directly integrated with the database.

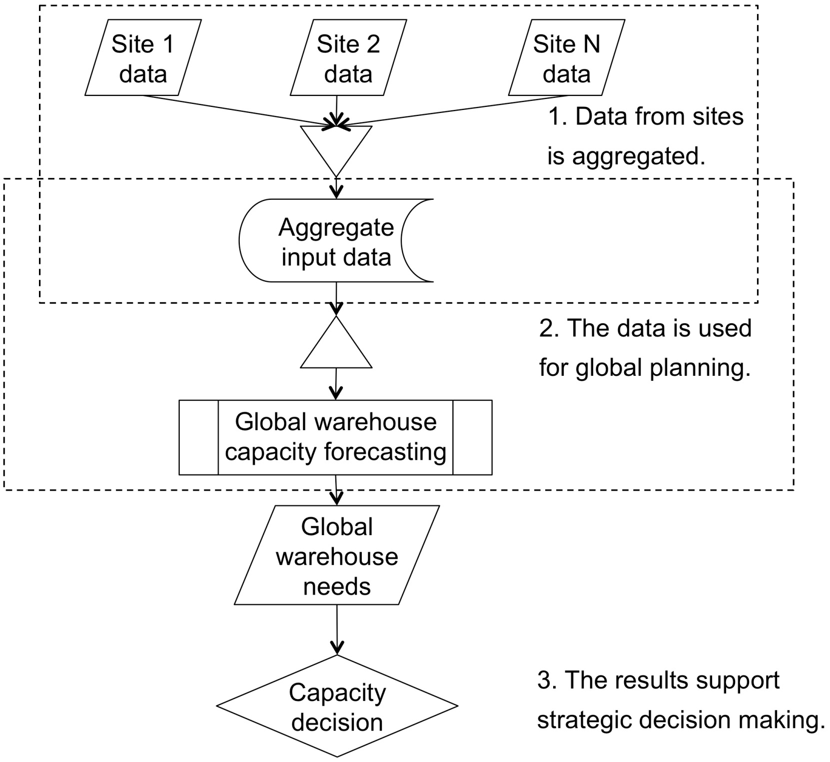

Figure 3: The process for data collection and global warehouse capacity forecasting.

Although individual sites may provide their input data directly for the forecast process, the data is still stored in a central database. Therefore, it is still centralized although not necessarily collected by a separate central function. In this case, the department conducting the global forecasts for warehouse capacity would be the owner of the database. In the case of another function collecting the input data from individual sites, that function would be the data owner, and it would provide the site level input data for global warehouse capacity forecasting.

7. Evaluation of results and future research directions

7.1 Summary of results

The interview results provided descriptive information on the characteristics of good warehouse capacity planning processes, since the respondents formed an informative group. The findings formed a basis for the recommendations given to Nixoran. While recommendations for the use of specific tools could not be given, the interview results pointed to the direction of dedicated and often in-house developed warehouse capacity planning tools. Also, the integration of the planning tools to other systems was an important topic. These findings provide a basis for deciding the exact tool platform in the future.

The most valuable lesson of the interview series was that the initial research problem was not only related to the operational capability and accuracy of a prospective planning tool. At least as important are the data management of the input and output data and the integration of the tool to other systems to ensure effective and efficient use of the tool.

The concept testing proved the Historical scaling approach to lend itself well for future development. The testing done with data from Site A showed that Nixoran may already have most, if not all of the required data for forecasting long-term warehouse capacity needs. Also, a first prototype of the prospective forecasting tool using the Historical scaling approach was successfully created.

The recommendations given in chapters 5 and 6 provide the mother project and Nixoran with problem points in Nixoran's current planning process and important aspects for improving the forecast process and tool. By solving the current problems in data management and tool integration Nixoran can make the first forecast tool simple and more reliable. Further tool development will also be easier, since the capability of an existing process and tool are easier to evaluate and benchmark, when their structure and relation to other systems are clear.

7.2 Uncertainties related to the interview results

The purpose of the interview series was to collect long-term warehouse planning processes and tools used in other manufacturing industries and apply the lessons from them in evaluating warehouse capacity modeling concepts for Nixoran. The interview series provided knowledge on the characteristics of good planning processes, but specific tool features or detailed process descriptions were not captured due to two reasons. First, the explorative nature of the interview series meant that a high-level approach for warehouse planning was taken and multiple industries were included. Second, not one single tool was identified to be more widely in use than any other.

7.2.1 Interview result uncertainties due to the chosen interview methodology

It was expected that as the size, business logic and markets varied a lot even within one industry, any general, industry specific conclusions could not be drawn. For example, one of the cosmetics companies sells its products to consumers via sales agents, while another sells its products to other companies. Also, the amount of in-house operations at the different stages of the supply chain differs between the two companies. The third cosmetics company is smaller and has less international operations than the other two. As a conclusion, in each industry there are still more granular market segments that different companies serve with differing strategies and supply chains. Therefore, in order to make any generalizations, the unit of analysis would have to be a sub-category of an industry, for example, the cosmetics companies that sell to other companies, receive over 50 % of their sales from a specified geographical area, have an annual revenue between € 100 and 500 million and have outsourced at least 50 % of their distribution operations.

The sample of the interviewed persons hardly gives a representative view on the operations of the companies. Especially in larger companies, one person is not knowledgeable enough to tell about the whole supply chain and all operations spanning from primary manufacturing to distribution centers. Thus, the interview results were incomplete and highly subjective. To reach more reliable, company-specific results, a company wide interview series would have to be conducted with interviewees who have specialized in different operations in the supply chain. It would also have to be assured that the areas of expertise of the interviewees overlap, so that the there are no gaps in the group's combined knowledge on the supply chain.

The interview series concentrated on only single companies, so the other parts of their respective supply chains were not analyzed. Consequently, the characteristics of a good supply chain were only asked from the manufacturers, not from end-customers. Therefore, the actual customer requirements regarding flexibility, responsiveness and other supply chain attributes were not captured in this study. The viewpoint of a supplier was left out, too.

7.3 Gaps in tool concept development and evaluation

The three tool concepts were initially evaluated based on the currently available data at Nixoran's Site A. While this approach limited the perspective to a singular case, it provided valuable in-depth lessons on the possible limitations in data quality and system integration at Nixoran sites. Although other sites may have more or less the same problems, the important findings were the pitfalls and limitations imposed by incomplete or inaccurate input data and insufficient system integration.

Two of the concepts were initially evaluated with data from Site A and their reliability was partially tested by comparing the modeling results with history data. Although the third alternative was not tested, this was due to the deficiencies of input data quality, which prevented the development of a first working model. Thus, the evaluation of the third concept alternative was incomplete, but the limitations imposed on its initial implementation were understood and found to be very restrictive.

All the required input data for the promising Historical scaling approach were not received so the final accuracy of the tool concept could not be justified. The assumptions behind the Historical scaling approach were quite limiting, as for example a stable demand was assumed. Yet, four of the six assumptions could be stated to be reasonable and the validity of two was partially proven. Still, the assumptions have to be tested repetitively in the future to make sure that the concept is still valid.

7.4 Further development of the Historical scaling approach

Ideally, the demand and inventory data would be available on a daily level so they would provide a more accurate representation of the demand distribution. Unfortunately, these data are not currently available at Nixoran's Site A; only static inventory information for any given date are available, and even those have to be manually extracted. Using daily inventory information, the accuracy of the Historical scaling approach could be estimated and proven more reliably as the variance of inventory levels could be calculated. However, this data has to be combined with the separate data on inventory movements, because an inventory's physical and nominal location can be different. With these data pieces the average demand and its variation per warehouse can be calculated.

As stated by Fisher (1997), innovative products require flexible and functional products require efficient supply chains. This logic could also be used for long-term warehouse capacity modeling by using different models for different product groups. Fast moving and high-value products would benefit from more accurate calculations while low-cost products with lower revenues may be managed with less elaborate methods. From the three evaluated concepts, the Historical scaling and Bottom-up approaches could be used for the most important products while the less accurate Clustering approach may be enough for less important product categories.

7.5 Improving the supply chain beyond warehouse planning

According to the interview results, in the semiconductor and high-technology industries standardization was a widely used approach for coping with changing market conditions, handling the transitions between product generations and managing other uncertainties. The standardization was used not only in products and production technologies, but also in logistics processes. For example, in one company one main principle was to create modular supply chain processes that could be used to meet the individual customer needs and leverage the individual advantages provided by different suppliers. This was complemented with close customer and supplier collaboration with the following practices and targets:

1. Build a flexible and reliable supplier network.
2. Identify improvement areas in supply operations in cooperation with suppliers and customers.
3. Arrange supplier forums to discuss and agree on the development areas with the suppliers.
4. Arrange customer forums to propose best suppliers and customize customer specific supply chains according to customer needs.
5. Concentrate on increasing flexibility by creating modular supply chain processes that are standardized and can be combined to meet changing customer needs.

Perhaps the most difficult but also the most advanced practice of the ones mentioned above is the developing of modular supply chain processes. This could mean, for example, having different shipment options available for one customer and one product: depending on the market, the product could be either delivered directly to the point-of-sale, delivered to the customer via distribution centers or delivered directly to the facilities of the customer's customer. Having this kind of flexibility makes the flow of goods in the supply chain more effective, since individual customer and product characteristics dictate the requirements for speed and the target for the flow of goods. Doing it cost-efficiently is another question, but also important, since the flow of goods has to be justified by the goods' importance in the value creation process.

Especially when the accuracy of forecasts can be expected to decrease in the future, increasing flexibility becomes more important. When this approach is applied to warehousing, it suggests, that the effort put into the planning of inventory levels and warehouse capacity does not have to be increased in-house. On the contrary, additional effort should be put into the creation of warehousing networks and the forming of partnerships with 3PLs, so that the warehouse capacity can be adjusted on a short notice. Also, the need for warehousing should be re-evaluated, if direct deliveries to customers and other new logistics models can be used. Therefore, the analyzing of warehouse capacity should be started only after the storing of goods is justified. Even after that, the most detailed forecasting of warehouse capacity should be complemented, if not substituted, with creating a flexible warehousing network that can accommodate unexpected changes in product volumes and storage needs.

7.6 Other research areas

Although pallets currently form an important part of the warehousing operations at Nixoran, this may not be the case in future. If the company implements vendor managed inventories and just in time production, the role of warehousing will change. Therefore Nixoran should in its long-term planning not only evaluate its current capacity against future needs, but also ask, if the current modes of operation will be used in the future. Should the modes of operation change, for example via the adoption of lean production, the planning of warehouse capacity with the current models is not as useful.

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9. Appendix A: Interview data and results

Table 12: The comparison of characteristics of different industries. (Shah, 2004) (Davidson & Greblov, 2005) (Cento, 2009) (Tiwari, 2005) (Farahani, 2011) (Akkerman;Farahani;& Grunow, 2010) (Sturgeon;Memedovic;Van Biesebroeck;& Gereffi, 2009) (Vermooten, 2004) (Bureau of Economics, 2004)

	Pharmaceutical	**Semiconductor**	**Petroleum**	**Airlines**	**Automotive**	**Retail**	**Food processing**	**Jet engine manufacturing**
Product volumes	Low to moderate	High	High	-	High	High	High	Low
Product value	High	Low to moderate	Low	Low to moderate	High	Low	Low	High
Product complexity	High	High	Low	Low	High	Low	Low	High
Temperature-controlled storage required	Yes	Yes	Yes	No	No	No	Yes	No
Product life cycle	Medium (research - based)	Short	Long	-	Medium	Short	Long	Long
Dominating production mode	Batch	MTO	Continuous	-	MTO	-	Batch	MTO
Cycle times	Long	Short	Medium to long	-	Medium to long	Short	Short	Long
Supply chain segmentation	High	-	-	-	.	-	-	High

Table 13: The interviewed companies, company representatives and company ICB classifications.

Industry	Revenue in 2012 (millions)	Company representative's title	ICB sub-sector classification	ICB sub-sector code	Interview location	Interview date
Automotive	EUR 77'000	Process Manager, Supply chain planning	Automobiles	3353	Munich, Germany	July 2nd 2013
Automotive	EUR 190'000	Head of Global Network and Depot Planning	Automobiles	3353	Kassel, Germany	July 4th 2013
Cosmetics	Undisclosed	Plant Manager	Personal Products	3767	Schlieren, Canton of Zürich, Switzerland	June 24th 2013
Cosmetics	EUR 1'500	Senior Vice President - Global Supply	Personal Products	3767	Stockholm, Sweden (telephone call)	July 5th 2013
Cosmetics	CHF 380	Head of Logistics and Distribution	Personal Products	3767	Buchs, Canton of Aargau, Switzerland	July 11th 2013
High-technology electronics	USD 120'000	GSD Supply Chain GWE Manager	Computer Hardware	9572	Dübendorf, Canton of Zürich, Switzerland	June 11th 2013
High-technology electronics	EUR 390	Senior Vice President, Supply Chain	Industrial Goods and Services	2730*	Hong Kong, (telephone call)	June 26th 2013
Semiconductor	EUR 180	Head of Department Planning/Logistics	Semiconductors	9576	Dortmund, Germany (telephone call)	June 25th 2012
Semiconductor	USD 54'000	Logistics Systems Capability Manager	Semiconductors	9576	Amsterdam, Netherlands (telephone call)	July 311st 2013

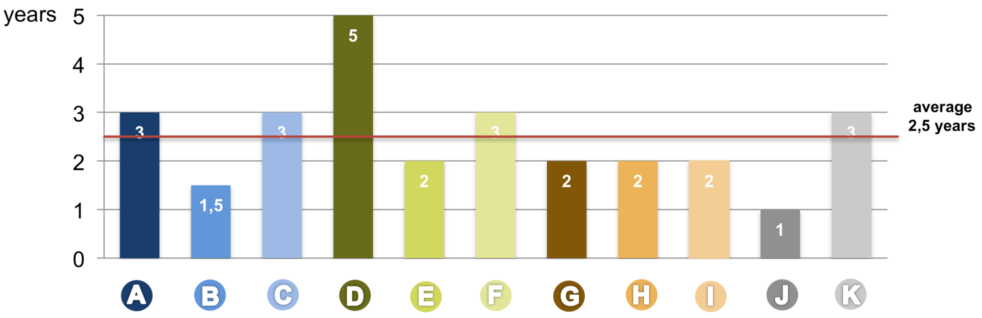


Figure 4: The span of accurate forecasts for warehouse capacity in the pharmaceutical companies. Picture received from Felix Friemann.

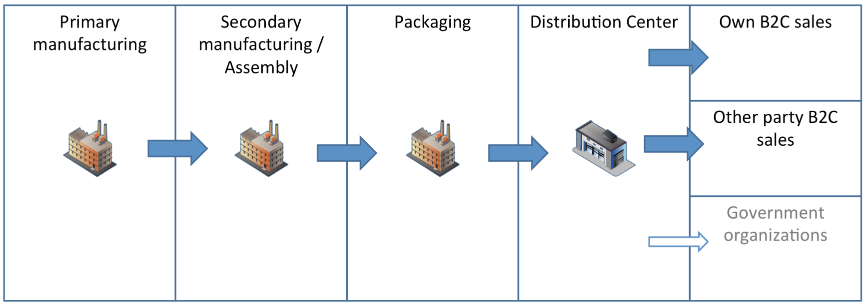


Figure 5: The representation of the parts of the supply chain within one interviewed company.

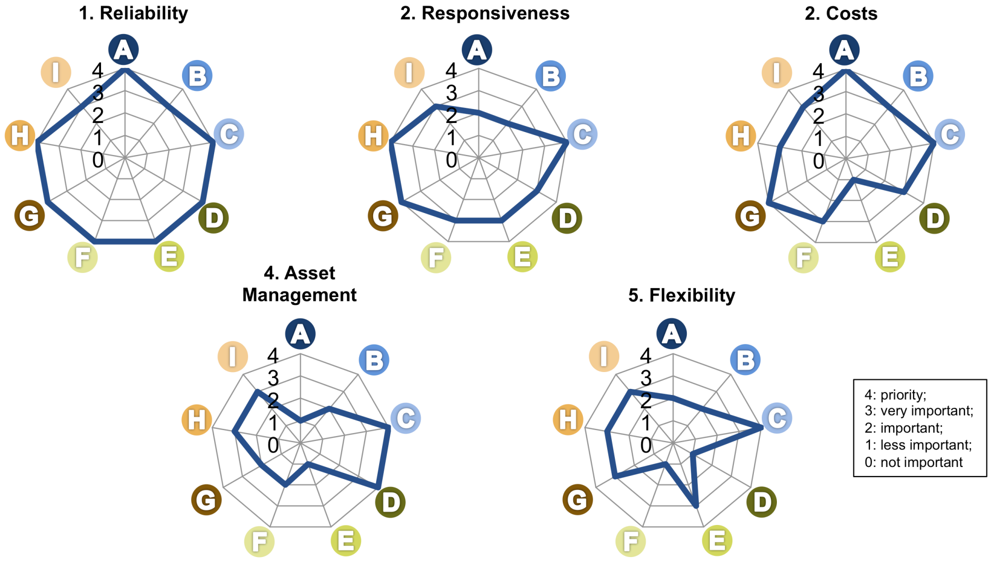
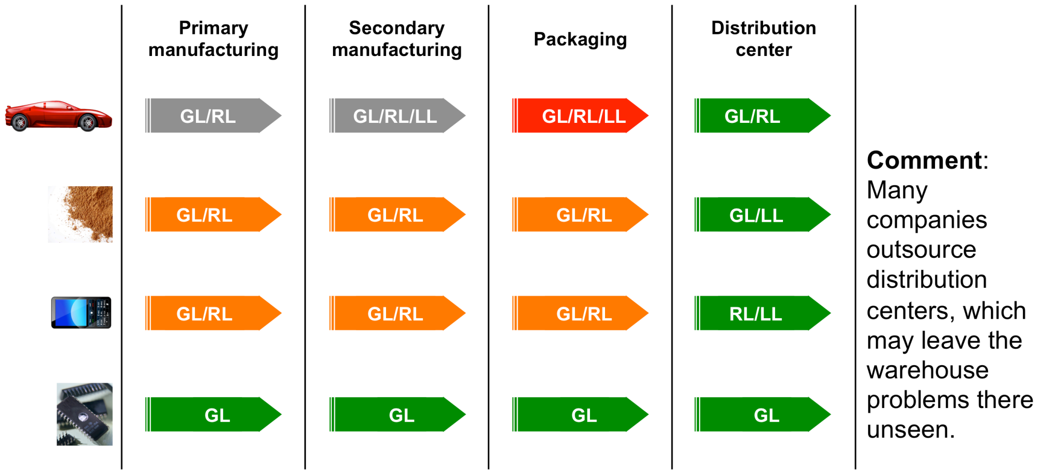


Figure 6: The importance of the SCOR first level metrics to the interviewed companies.



Comment: Many companies outsource distribution centers, which may leave the warehouse problems there unseen.

Figure 7: The extent of global operations and problem areas in warehousing. The order of the interviewed industries from top to bottom: automotive, cosmetics, high-technology electronics and semiconductors.

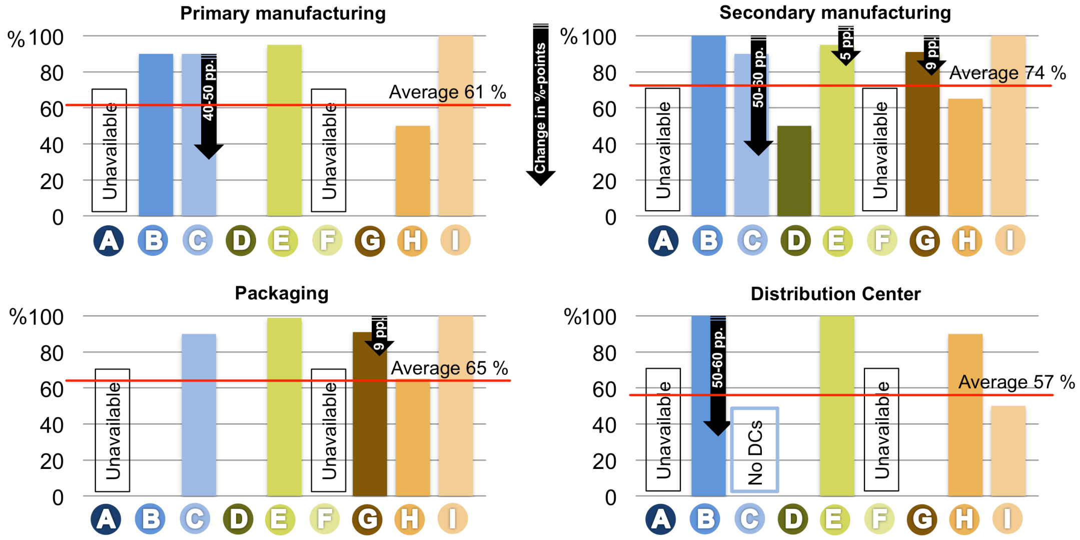


Figure 8: The current level of in-house operations and future plans for outsourcing.

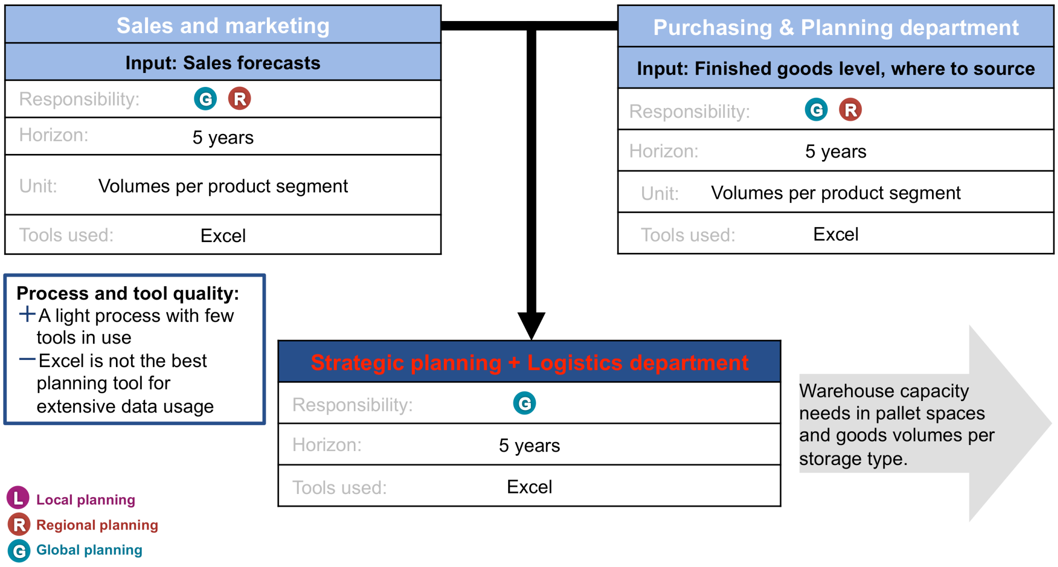


Figure 9: The representation of the Model 1 planning process for warehouse capacity.

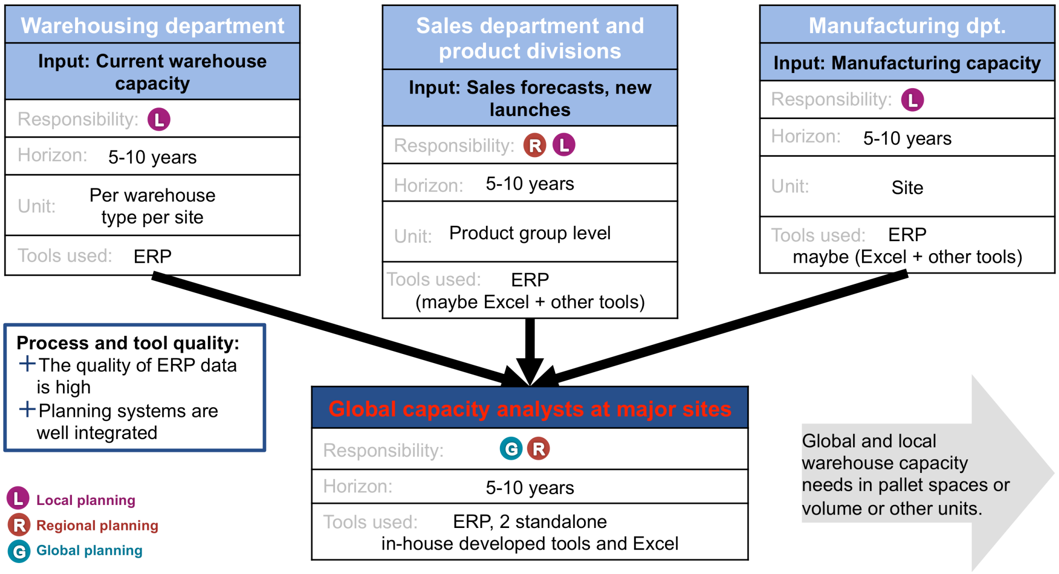


Figure 10: The representation of the Model 2 planning process for warehouse capacity.

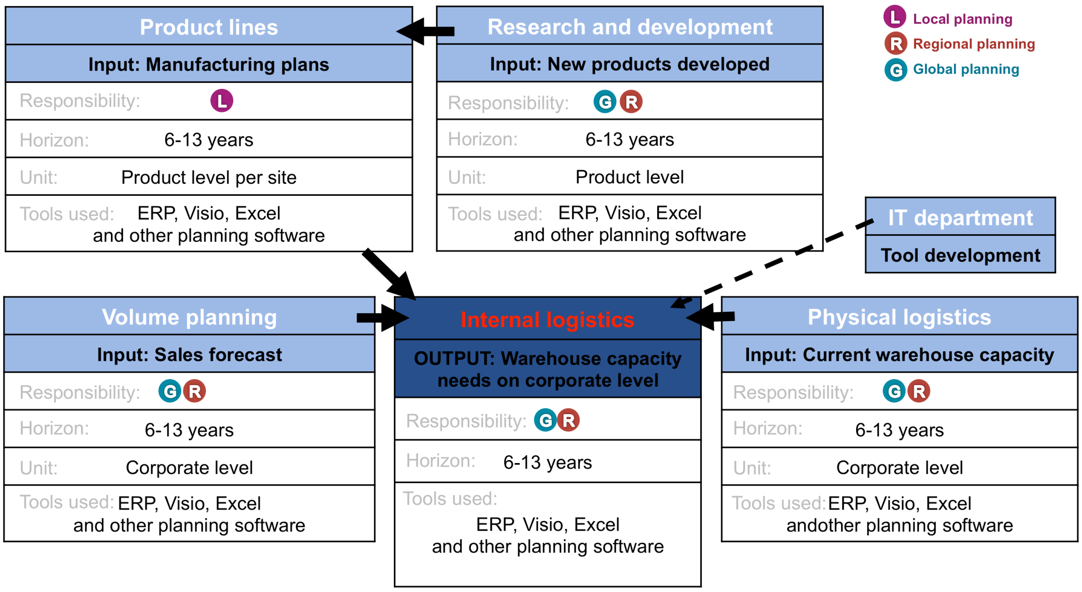


Figure 11: The representation of the Model 3 planning process for warehouse capacity.

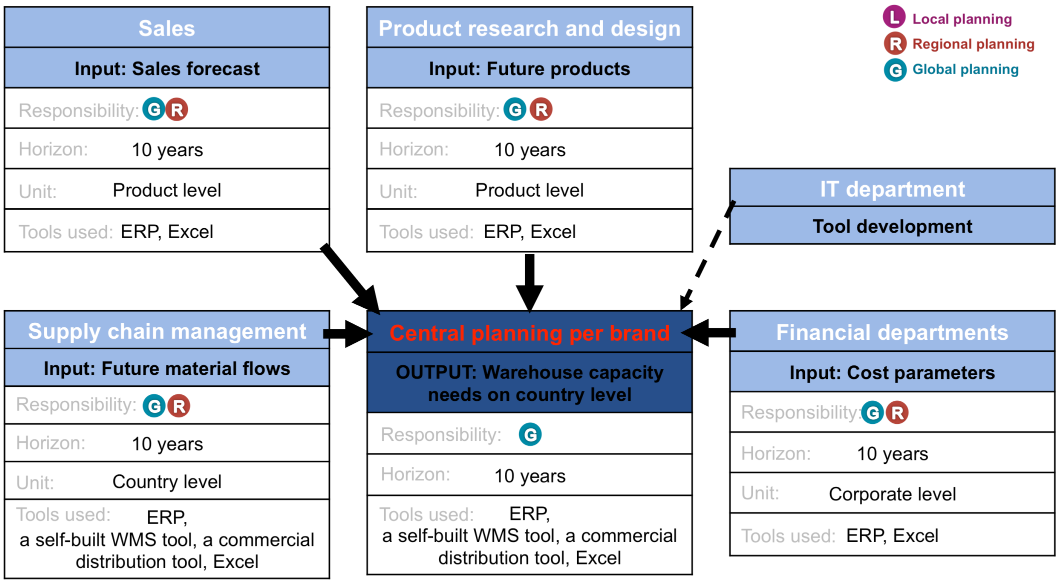
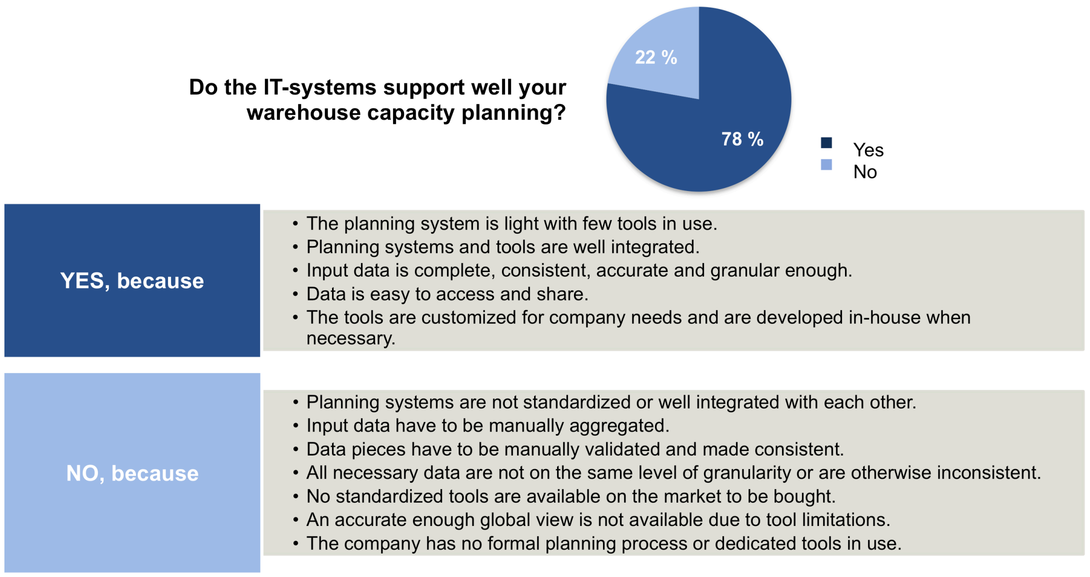


Figure 12: The representation of the Model 4 planning process for warehouse capacity.



YES, because

- The planning system is light with few tools in use.
- Planning systems and tools are well integrated.
- Input data is complete, consistent, accurate and granular enough.
- Data is easy to access and share.
- The tools are customized for company needs and are developed in-house when necessary.

NO, because

- Planning systems are not standardized or well integrated with each other.
- Input data have to be manually aggregated.
- Data pieces have to be manually validated and made consistent.
- All necessary data are not on the same level of granularity or are otherwise inconsistent.
- No standardized tools are available on the market to be bought.
- An accurate enough global view is not available due to tool limitations.
- The company has no formal planning process or dedicated tools in use.

Figure 13: The proportion of companies satisfied with their current planning tools.

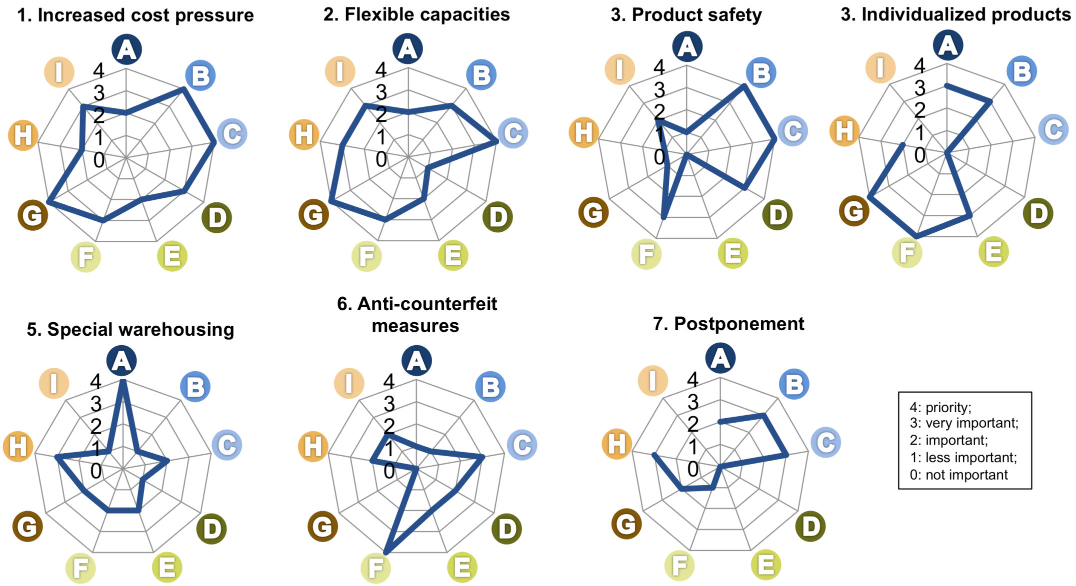


Figure 14: The relative importance of selected future trends for the interviewed companies.

10. Appendix B: Interview template

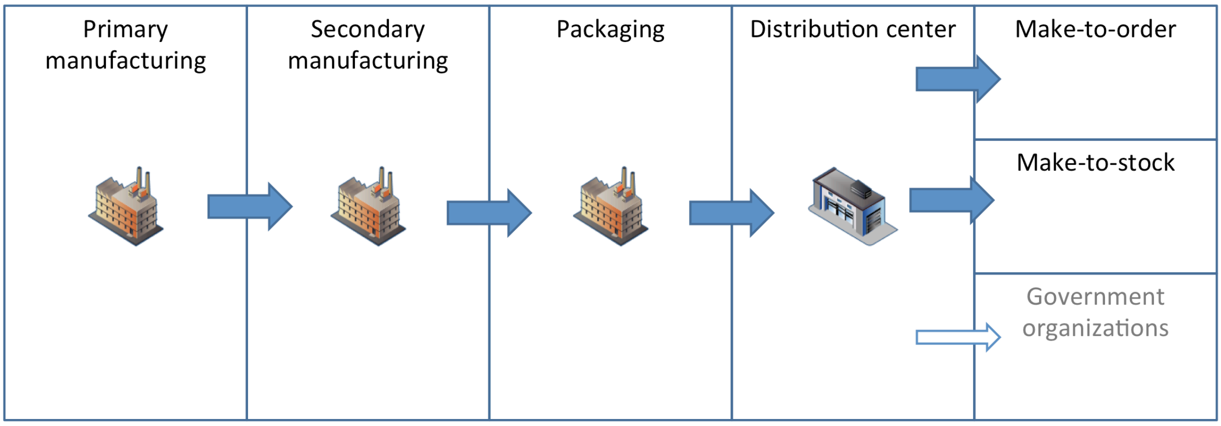
Part 0: General information (3 min)

Date:	
Location:	

Company information (referring to the year 2012)
Name:
Headquarter:
Industry:
Yearly revenue:
Employees:

Interviewee information
Name:
Position:
How many years have you been in the company or worked in the industry?

General representation of your supply chain. Please correct if necessary.



Part 1: Supply chain structure and performance measurement (30 min)

In this part we collect general information about your supply chain. This information evaluates the different concepts currently applied in supply chains.

1.1 **Are the following factors important trends for your supply chain in the next 10 years? If yes, do you expect challenges?**	**4 (Yes and I expect big challenges)**	**3 (Yes and I expect challenges)**	**2 (Yes and there may be challenges)**	**1 (Yes but I do not expect challenges)**	**0 (No, not a trend)**
Special warehousing requirements and capacities, specifically ____________________	○	○	○	○	○
Flexible capacities, specifically ____________________	○	○	○	○	○
Increasing cost pressure on finished goods	○	○	○	○	○
Anti-counterfeit measures	○	○	○	○	○
Product safety for end-user	○	○	○	○	○
More individualized products according to customer needs and wishes	○	○	○	○	○
Postponement	○	○	○	○	○
Other:					

1.2 **Referring to 1.1: What are the two most important tools / practices you plan to use to overcome these challenges? (Most important tools regarding the whole spectrum of alternatives.)**
Tool / practice number one…
Tool / practice number two…

1.3 Which industries do you see as top performers in the following areas of supply chain management?	Supply chain risk management	Collaboration with suppliers/customers	Transparency throughout supply chain	Flexible/Agile logistics capacities
Automotive	○	○	○	○
Pharmaceutical	○	○	○	○
Cosmetics	○	○	○	○
Aerospace	○	○	○	○
Semi-conductor	○	○	○	○
High-tech electronics	○	○	○	○
Retail	○	○	○	○
Other:				

The Supply Chain Operations Reference (SCOR®) model helps manage a common set of business problems through a standardized language, standardized metrics, and common business practices. From the SCOR model, different performance attributes exist:

Performance Attribute	Performance Attribute Definition	Level 1 Metric
Supply Chain Reliability	The performance of the supply chain in delivering: the correct product, to the correct place, at the correct time, in the correct condition and packaging, in the correct quantity, with the correct documentation, to the correct customer	Perfect Order Fulfillment
Supply Chain Responsiveness	The speed at which a supply chain provides products to the customer.	Order Fulfillment Cycle Time
Supply Chain Flexibility	The agility of a supply chain in responding to marketplace changes to gain or maintain competitive advantage.	Upside Supply Chain Flexibility Upside Supply Chain Adaptability Downside Supply Chain Adaptability
Supply Chain Costs	The costs associated with operating the supply chain.	Supply Chain Management Cost Cost of Goods Sold
Supply Chain Asset Management	The effectiveness of an organization in managing assets to support demand satisfaction. This includes the management of all assets: fixed and working capital.	Cash-to-Cash Cycle Time Return on Supply Chain Fixed Assets Return on Working Capital

1.4 **Referring to the SCOR model: Which performance attributes have the most importance for your supply chain?**	**4 (priority)**	**3 (very important)**	**2 (important)**	**1 (less important)**	**0 (not important)**
Reliability	○	○	○	○	○
Responsiveness	○	○	○	○	○
Flexibility	○	○	○	○	○
Costs	○	○	○	○	○
Asset Management	○	○	○	○	○

`

1.5 **Can you provide an example of how you measure these performance attributes in your supply chain?**	**KPI**
Reliability	
Responsiveness	
Flexibility	
Costs	
Asset Management	

1.6 How are the two most important KPIs to your supply chain defined?

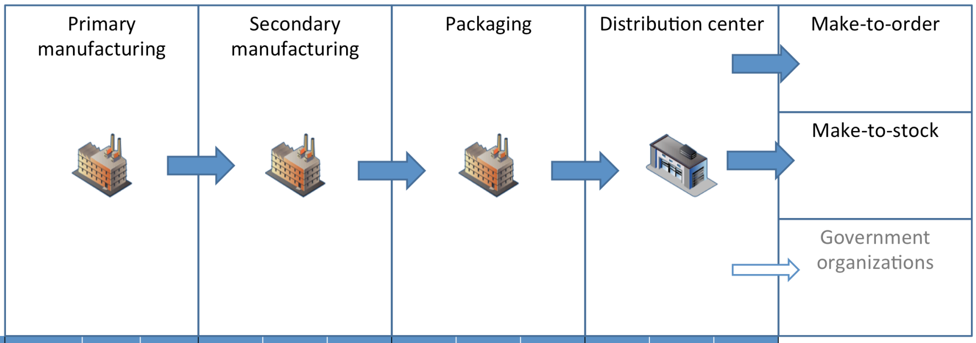
KPI 1:

KPI 2:

Do you think these will change within the next 10 years?

1.7 Outsourcing: What reasons do your outsourcing decisions mainly depend on?

1.8 Which stages of your supply chain are supplying on a global, regional or local level? Which stages do you outsource?

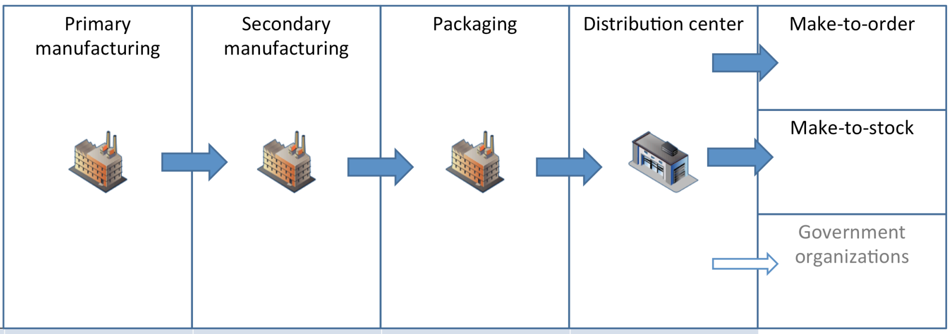


		G	R	L	G	R	L	G	R	L	G	R	L
Mainly operating on global / regional / local level	As-Is	○	○	○	○	○	○	○	○	○	○	○	○
	Planned (target)	○	○	○	○	○	○	○	○	○	○	○	○
Percentage of operations in-house / outsourced (in terms of volume)	As-Is		/	%		/	%		/	%		/	%
	Planned (target)		/	%		/	%		/	%		/	%

1.9 Integration: Do you expect a change in the capabilities of your supply chain's actors in the future? If yes, please specify.	**Yes**	**No**
We expect a change in the capabilities of the actors in our supply chain.	○	○
Types of change: (e.g. more capabilities of network integrators, R&D companies with no manufacturing, manufacturers for niche products of our product portfolio)		

1.10 Referring to 1.9: The main drivers for the increased focus of the operators will be:	**3 (very strong driver)**	**2 (strong driver)**	**1 (moderate driver)**	**0 (Not sure)**	**-1 (not a driver)**
Cost pressures that force to focus on core competencies	○	○	○	○	○
The need for a more agile supply network	○	○	○	○	○
A more complex product mix	○	○	○	○	○
Supply chain segmentation	○	○	○	○	○
Differences in product variants between markets	○	○	○	○	○
Others:					

1.11 What is the average warehouse capacity utilization in your network?



		Primary manufacturing	Secondary manufacturing	Packaging	Distribution center
Number of facilities	No.				
Avg. warehouse capacity utilization	%				
Target warehouse capacity utilization	%				
Flexibility: Possible volume increase	%				

Overall utilization on average [in %]:

What is the total cycle time (meaning Part manufacturing to DC) on average [in days]:

1.12 Do you follow a common approach (e.g. close to customer, central warehousing) for your distribution? Why?

1.13	**Segmented supply chain: Are your service level targets identical company wide? If not, where do you differentiate or plan to differentiate?**

Yes, same targets company wide ○

No, they are different and depend on (e.g. region, product value, channel, risk balanced approach):

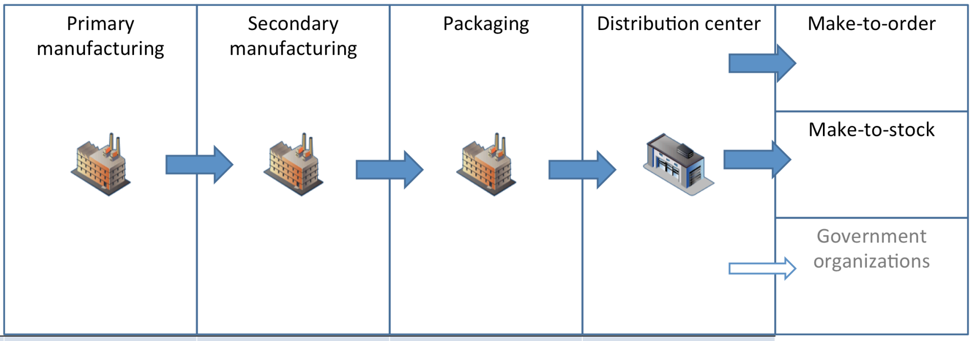
Part 2: Mid- to long-range warehouse capacity planning (20 min)

In this part, specific strategies for capacity planning within your supply chain will be analyzed.

Warehouse capacity:

By warehouse capacity we mainly mean storage capacities in terms of pallet spaces.

2.1 Would you say that *warehousing capacities* *<u>(storages)</u>* have been critical in the last years when launching/introducing new products?



		Primary manufacturing	Secondary manufacturing	Packaging	Distribution center
Yes, highly limited warehouse capacity	As-Is	○	○	○	○
Yes, warehouse capacity limitations encountered in the past	As-Is	○	○	○	○
Not critical	As-Is	○	○	○	○

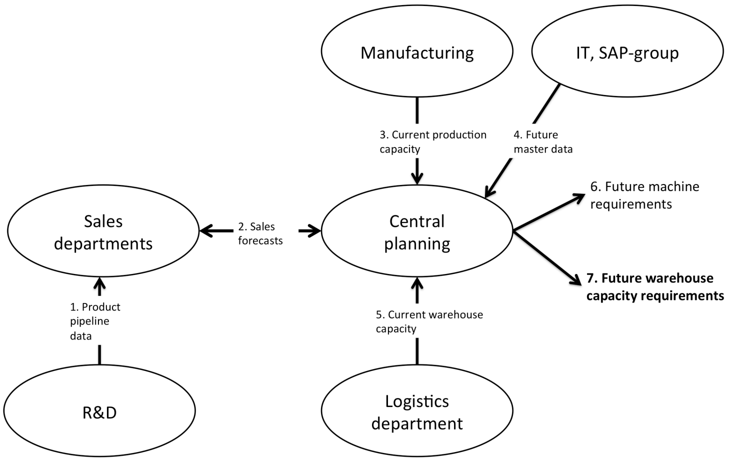
2.2 Referring to 2.1: Do the limitations depend on …	**3 (strongly agree)**	**2 (agree)**	**1 (partly agree)**	**0 (Not sure)**	**-1 (do not agree)**
Special requirements (e.g. temperature or humidity) of the product	○	○	○	○	○
Geographical region	○	○	○	○	○
Internal / External capacities	○	○	○	○	○
Safety requirements	○	○	○	○	○
Others:	○	○	○	○	○

2.3 Do you have a central department for mid- to long-range planning (e.g. 2-10 years) of warehouse capacities?	**Yes**	**No**
Do you have a central department for mid- to long-range planning of logistics capacities?	○	○

If not, who is responsible for it?	
On which level do you plan warehouse capacities (e.g. pallet spaces, volume on product family basis)	
What is your long-range planning horizon?	____________years

2.4 **Which departments are involved in mid- to long-range planning (e.g. 2-10 years) of warehouse capacities? What inputs do they provide, which reports do they use, what is the sequence?**

A fictitious example:



2.5 Which systems/programs the above-mentioned departments mainly use for mid- to long-range planning of warehouse capacities?

Department	IT-Systems used (e.g. SAP APO, Excel, Standalone program)

How does your IT structure support this process?

2.6 Warehouse capacity planning process and the supporting IT-structure: Do you encounter specific challenges? Do you plan to change the process and capabilities in future?

2.7 Long-range warehouse capacity planning: What is the trigger for acquiring new warehouse capacity (e.g. customer proximity, increasing sales, new product introductions)?

2.8 Forecast accuracy: What is the time horizon for which you would consider your warehouse capacity (storage) forecasts as reliable? Can you give an accuracy level?

___________________________ [years], level of accuracy ±_________%

2.9 Agility: What are the most critical warehouse capacities (storage) to be increased? How long does it approximately take to increase them?

… take ___________________________ [months]

2.10	**How do you aim to decrease uncertainties in long-term planning (e.g. by using new forecast models, improving data timeliness, validating data via centralized data management)?**

Part 3: Future trends of the industry (10 min)

In this part we collect industry specific trends, the challenges they pose and possible solutions. The results help to identify good approaches to specific supply chain problems.

3.1 What significant supply chain practices have you recently implemented or plan to implement in the coming years?	**Yes, implemented**	**Will implement in the future**	**No, not implemented**
Product tracking in the supply chain	○	○	○
Mobile applications / tools in supply chain management	○	○	○
High-level collaboration (e.g. decision making, exchanging sensitive information) with suppliers	○	○	○
High-level collaboration (e.g. decision making, exchanging sensitive information) with customers	○	○	○
Supply chain development as part of new product R&D	○	○	○
Other:			

3.2	**Referring to 3.1: What is the scope of these practices? What everyday tools are used to execute them?**

3.3	Will the role of your company change in the future supply network? How do you plan to achieve your new position?

In the future supply network our company will be…

3.4	Emerging markets: Do you consider other than the BRIC countries (Brazil, Russia, India and China) as emerging markets?

No ○

Yes, the following:

3.5 Emerging markets: What are the biggest challenges at the emerging markets?	4 (Highly critical in all markets)	3 (Critical in all markets)	2 (Critical in some markets)	1 (Partly critical in some markets)	0 (not critical)
Availability of qualified personnel	○	○	○	○	○
Increasing regulatory requirements	○	○	○	○	○
Product supply	○	○	○	○	○
Unfamiliar demand drivers and patterns	○	○	○	○	○
Others:	○	○	○	○	○

Thank you for your participation