1 Introduction

1.1 Research Motivation

The current global automotive industry is characterized by a geographical dispersal of production and consumption /CHAN77/, /PINE93/, /SCWI00/, /HLS00/, /HUMP01/. The supply networks of the automotive industry stand out through their particularity in a high degree of complexity and variability. That is why the automotive supply chain and supply network has been a subject of extensive research both in operational and academic fields with many different focuses /WHIT02/, /HOPI04/, /HOLW04/, /TUWI05/, /TURN05/, among which the flow of completely knocked down (CKD) deliveries represents one of the key elements.

To put it simple, CKD is one type of global sourcing. The CKD parts flow from the mother company to the overseas original equipment manufacturers (OEMs) or in between the OEMs, which implies the global economic integration and constructs a complex supply network /DICK98/, /KNAG98/, /FMSV98/, /STFL99/, /HMGP99/, /BBL00/.

However, CKD is more than distribution to supply the OEM production. The selection of CKD suppliers are commonly strictly centralized i.e. controlled by the mother company and the OEMs can only purchase the CKD parts from the suppliers who are qualified by the mother company. From the mother company's perspective, CKD is an important strategy to balance the group interests in a worldwide "localized" production. On the other hand, from the perspective of the CKD receiving OEM, the long lead time for CKD delivery, the delay in information transfer, and the demand to satisfy the production plant often makes the OEMs to rather sacrifice the costs for the time. All these make the situation more difficult within a fierce competition environment where competitors can provide "cheaper" cars.

Hence, the questions of how to make the CKD process more transparent, how to choose the appropriate CKD strategy in different emerging automotive market, and how to evaluate the CKD performance under the dynamic global supply networks have attracted much attention and practical concern among international automotive manufacturers during recent years. However, very little concrete research has been devoted to this topic.

Based on this background, the Fraunhofer-institute for Material Flow and Logistics (IML) has initiated the research on CKD processes.

2 Historical Review

2.1 Development of CKD Research

Logistics was initially developed for military purposes and operations. In the 1950's[6] it was taken to the civil domain and applied to the functions of production, distribution and consumption /ROSL02/. Since then, logistics has developed, on both a theoretical and practical level, into a widely recognized discipline of significant importance[7] /DEEP07/.

2.1.1 Development of Supply Network in Automotive Logistics

The contemporary automotive production and distribution process is no longer subject to the activities of a single firm, but is increasingly practiced in complex networks of suppliers and subcontractors /DITH92/, /GERT92/, /HUDS01/. Figure 2-1 shows one example of a supply network structure.

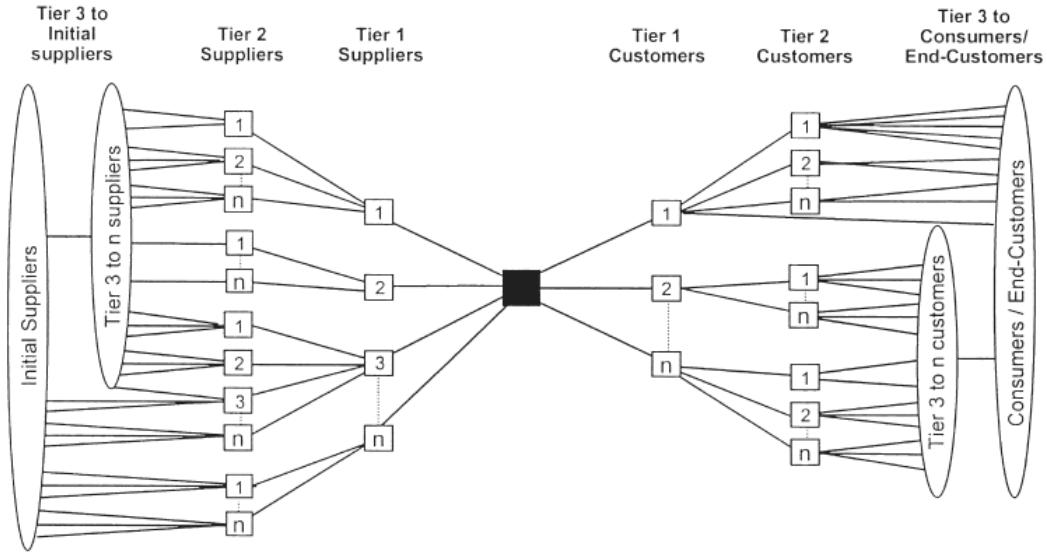

Figure 2-1 Automotive Supply Network Structure

For a core company in the middle, the inbound logistics include the supply from the n^{th} tier suppliers till the 1^{st} tier suppliers. And the outbound logistics is to distribute to the customers and the customers' customer. Supply chain management (SCM) aims at

[6] The concept of logistics in its modern form dates back to the second half of the 20th century /DEHL01/, /WEKU98/, represented by the principles from Ford, when his ideas such as sequence, duration, schedule, rhythm, synchronization and time perspective related to improving efficiency within the factory by organizing the workers' tasks along an assembly line are of high significance to logistical management /TAYL47/.

3 CKD Typology

The last few decades have been defined as the period of expansion and globalization[24] of enterprises. One significant example is the automotive industry /PORT86/, /BERG96/, which does not only reflect the automotive manufacturers' globalization, but also more dynamic and complex supply networks. The impact of global competition has forced the suppliers, manufacturers and distributors to collaborate in an entire network /JJCP02/.

Logistics thus developed with the background of long-term structural changes in economy, technology and society affecting all major industrialized and emerging countries /IMF01/. All these changes can be seen as part of a more general process of industrial restructuring driven by a new competitive environment. In a global industry, as opposed to a multi-domestic one, the position in each country affects the overall competitive position of an OEM /PORT86/. In the automotive industry, the modes of automobile production are also changing to better satisfy the demands in the local market, while at the same time to save costs and improve the efficiency /CHUN98/.

The following terms will be introduced before discussing them in further detail.

3.1 Introduction of CKD

3.1.1 Definition of the Terms

CBU (Completely Build-up Units), SKD (Semi Knocked Down), CKD (Completely Knocked Down), PbP (Part by Part) and SPO (Single Part Ordering) are commonly used terms by MNCs especially in the automotive, computer and electronics industries[25] as means of entering new (or protected) markets /TURU97/, /MORA00/, /VOLP02/, /ELKI06/, /SOKU08/. Here these terms are particularly referring to the automotive industry.

[24] /BERG06/ defines globalization as the changes in the international economy and in domestic economies that are moving toward creating one world market.

[25] For instance the colour TV assembly in India since the mid 1980's /KINR95/, and the information and communication technology (ICT) products manufactured in China in the 1990's /LUQI00/, /TAN02/, /HONG08/. Other more popular examples are from the automotive industry: since the beginning of World War II in Japan /SMIT90/, in the early 1960's in South Korea /MUSA96/, or more recently the motorcycle production in Vietnam in 1998 /FUMA99/, and the production of the Audi A6 in Audi's joint venture with the First Automobile Works (FAW) in Changchun, China in 2003 /WAJO04/.

4 CKD Process Analysis

Chapter 3 summarized the five different strategies to enter the emerging automotive markets in a CKD typology, due to the similarities in these five strategies and the concept development of a CKD typology. In the following chapters, the term “CKD” will be used as representative of all CKD-like processes.

4.1 Overview of a CKD Process

4.1.1 CKD Planning Process

The CKD process in the automotive industry is characterized by being both highly complicated and diversified, especially the planning process. Normally the CKD process starts from the sales forecasting of the vehiles in the import market (factory). The summary of the total sales of vehicles will be calculated and split into a part list, and will be ordered from different suppliers, which are located in the same country as the export factory. As illustrated in figure 4-1.

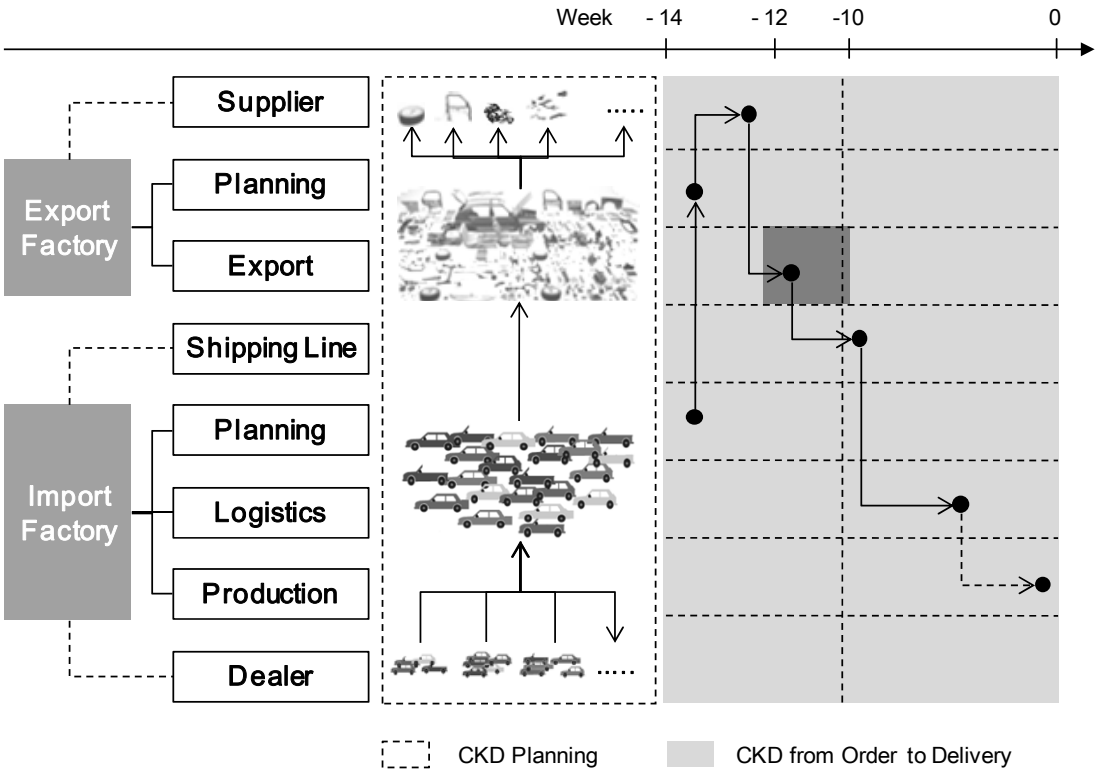

Figure 4-1 Overview of CKD Process

In comparison with a general logsiics process, the time from order to delivery for CKD parts are much longer. From the planning, order, delivery until the final assembly, the whole process is longer than three months.

5 CKD Processes Simulation

In the last two chapters, a CKD typology has been established and applied to different supply situations, and a subset of the attribute modules has been selected due to strategic, tactical and operational parameters. As described at the beginning of the dissertation, the temporal and spatial boundaries of CKD processes tend to be too far, which are dynamically deficient, omitting feedbacks, time delays, accumulations and nonlinearities[92] /STER00/, /BRUE03/, /TURN05/. It is the objective of the following chapter to find out a solution to test the various hypotheses stated before.

Such hypotheses testing on a model is known as simulation /SENG90/, /OET88/, which saves time[93] and determines the best solution support from various scenarios being tested[94] /DNT97/. Discrete-event simulation[95] permits models to be developed in greater detail and fidelity than systems dynamics. This approach has been very widely applied, particularly for studying complex problems under dynamic environments /TURN05/.

OTD-NET is a simulation and modelling tool using discrete-event simulation to analyze the order-to-delivery process in complex automotive supply networks. In this chapter, the parameter settings from the CKD typology and the scenarios brought forward in the CKD model will be extended with more precise data requirements in OTD-NET, thus to demonstrate how CKD processes can be integrated in OTD-NET simualtions.

5.1 OTD-NET

5.1.1 Order to Delivery (OTD)

Order-to-delivery (OTD) covers the order processing in a sales organization (market view) as well as the procurement and supplier management processes (production

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[92] In 1974, Thomas Naylor and Horst Schauland surveyed the planning practices of 2000 corporations in the USA, Canada and Europe. They concluded that in actual practice relatively few firms have managed to integrate the financial, marketing and production activities of the firm into a truly integrated corporate simulation model /NASC76/.

[93] Since simulation of many hypotheses can be done more quickly than by physical experiments /DNT97/.

[94] Simulations provide consistent stories about the future, but no predictions /MOST94/.

[95] Although the potential application of discrete-event simulation to investigate supply chain performance has been recognized, it is often considered impractical due to the need for high computational time /SKS00/, /AMR02/ and the large number of decision variables /LCKK02/. However, it is widely accepted and used in real-world applications, for example, in telecommunications equipment /PEOL02/ and pharmaceuticals /HKSS04/. Even in a survey in the UK it is found that the applications of simulation to supply chain processes are now most common, slightly ahead of production processes /MEPI03/.

6 Simulation of an Example CKD Case in OTD-NET

6.1 Definition of the Case

As introduced before OTD-NET is a dynamic simulation software for the automotive industry, and basically OTD-NET enables to simulate all processes from the order to delivery. In a complex CKD supply network, the concept of order to delivery can be interpreted differently in any single supply chain.

CKD supply is centrally controlled by the export plant for consolidation since the beginning phase of this concept. However, with the increase of the volume, and the development of different geographical locations of the suppliers and the car plants, it can be more cost saving when the supplier supplies the CKD parts directly from the supplier plant to the export port. However, this depends on many factors, for example: how much is the supply volume, where the all involved entities[124] are located, how this will affect the import plant (for example the inventory level).

Here it is defined that the order is from the import OEM, and will be delivered from the export OEM (or the 1st tier suppliers in the export OEM country). As illustrated in figure 6-1. Through a simulation, these questions can be answered in an accurate way.

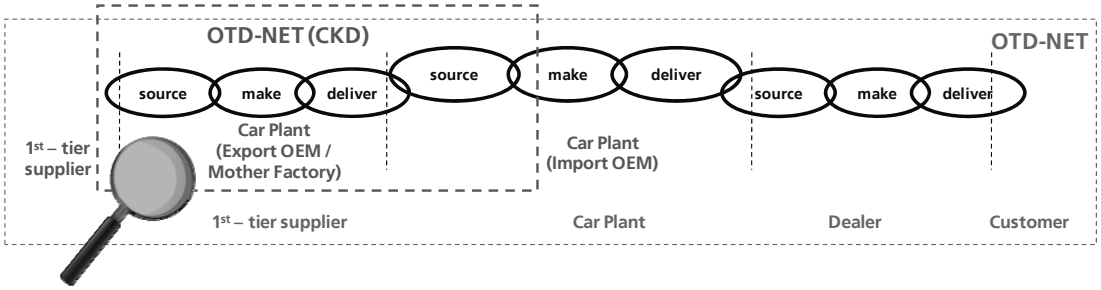

Figure 6-1 Scope Definition of the Problem

6.1.1 Scenarios

In this example simulation, the focus will put on two different scenarios of a CKD supply before export. The example scenarios illustrated here are exactly the alternative ways to supply CKD from the overseas suppliers in Germany to an automotive OEM in China /SSSWH08/.

[124] For instance: the suppliers, car plant, docking stations of the shipping lines and export port etc.

7 Conclusions and Outlook

7.1 Conclusions

This dissertation has analyzed the evolution of CKD processes during different automotive development stages and developed the tools for CKD process simulation and optimization. The key findings are the following:

7.1.1 CKD Typology

In the beginning of the dissertation, the different strategies (CBU, SKD, CKD, PbP, and SPO) to enter emerging automotive markets under different environments were defined, and a morphology to classify these variants according to strategic, tactical and operational level was outlined. Based on that, a subset of attribute models for the CKD typology was constructed.

The purpose of the typology is not to enlarge the differences between these strategies. On the contrary, due to the similarities of the CKD typology study, the term CKD was used as representative for all CKD-like processes in the succeeding chapters of this dissertation.

7.1.2 CKD Value Chain ABC Analysis

In a CKD value chain analysis, the CKD process was divided into four key process modules. These are inland transportation, international transportation, warehousing and customs clearance (including export and import customs clearance). The CKD process cost analysis was based on the concept of activity-based costing (ABC). The main cost drivers for each CKD key module (activities) were defined so as to make the whole CKD process a transparent overview. Various simulation topics were drawn from the CKD typology and CKD process description.

7.1.3 CKD Simulation

The objective of this dissertation was to show how to integrate the CKD processes into OTD-NET. The 20 main simulation topics in CKD supply were listed with detailed data requirements. In addition, PUZZLE was introduced to link to the OTD-system, so as to solve the container loading problem in CKD processes. Through a shared data server, the CKD orders from OTD-NET can be read automatically by PUZZLE. Based on the calculation in the PUZZLE system, the loading solutions were reflected in OTD-NET. Even when there are fluctuations in orders, PUZZLE can automatically update the input and output. In this way, the CKD process simulation