A SIMULATION-BASED METHOD FOR THE DESIGN OF SUPPLY STRATEGIES TO ENTER DEVELOPING MARKETS

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ABSTRACT
In this paper we provide a method to support decision makers selecting strategies for global supply chains during the life cycle of a product. As we focus on developing markets such as China or Latin America, we stick to supply strategies which we call “supply strategies to enter developing markets”. The method we present is divided into two steps. Starting with a definition and classification of these strategies a typology based selection method is used, clustering the strategies with respect to their elemental properties. Thus having pre-selected the strategies, due to the dynamic behaviour we use discrete-event simulation to have a closer look on the remaining options. Following this procedure, we are even able to achieve a more detailed setting of parameters such as stocks, capacities or transport frequencies. Within this paper we will focus on the second step of the method.

Keywords: supply chain design, discrete-event simulation, global sourcing, product life cycle

1. INTRODUCTION

The rising importance of emerging markets for western companies becomes especially apparent in the field of international Supply Chain Design (SCD). Hence, in recent years supply concepts such as Completely Knocked Down (CKD) and Part by Part (PbP) have been widely applied in order to supply newly established production sites in markets with steeply improving purchasing power.

However, shifting production steps to low-wage countries is not only motivated by labour cost advantages or the avoidance of import tariffs. Increasingly, strategic aspects such as hedging currency risks and building up a global sourcing base are taken into account which add new levels of complexity to international SCD policies. Since logistical requirements typically shift over a product’s life cycle, the need for a continuous re-assessment and redesign of the supply processes is evident.

In this paper, we introduce a method that provides decision makers in industry with feasible guidelines for the design of supply strategies to enter developing markets over a product’s life cycle.

The basis for the method is a comprehensive typology of such strategies. By setting the values of the parameters in the typology a limited number of feasible logistical strategies is identified. Then we apply discrete-event simulation, more specific the OTD-NET framework (Order-to-Delivery) created by the Fraunhofer IML in Dortmund (Wagenitz 2007; Toth, Hellingrath, Wagenitz and Klingebiel 2006) to decide between the remaining strategies. Furthermore by demonstrating through simulation that changing the supply strategy when sales are growing can save money, we will support the statement that an iterative re-design of the supply chain does make sense. Within this paper we focus on the second step of the method, while the first one will be discussed in detail in another publication (Sieben et al. 2008).

By following this approach, a transparent method for decision support with regard to supply strategies to enter developing markets can be derived.

The paper is structured as follows: In chapter 2 the so called supply strategies to enter developing markets will be defined and brought into a chronological order according to the product life cycle and market maturity. In chapter 3 the strategies will be classified using three sets of identifying attributes and the principle of the typology for the strategy selection is outlined. In chapter 4 the second step of the method applying simulation will be described and the discrete-event simulation environment OTD-NET will be presented. In chapter 5 a scenario out of the automotive industry to which the suggested method will be applied to is described and the results of the case study are presented. Chapter 6 will resume the research results and provide an outlook of further research and applications.

2. SUPPLY STRATEGIES TO ENTER DEVELOPING MARKETS

Since internationalization is a key factor of success for global enterprises, the establishment of products in emerging markets becomes more and more important. (Laux 1992; Moran 2000; Humphrey and Memedovic 2003; Petri 2004). Dealing with global supply strategies for these developing markets one can identify a certain set of strategies forming a chronological order due to the heights of sales and the market maturity. The main question is how to enter such a new market and especially what supply strategies are adequate for which type of product.

Assuming a protected market with a poor infrastructure of suppliers and instable sales, the first step to enter this market would normally be to sell completely manufactured products in the foreign country, avoiding risky investments. But when the sales grow higher and more stable decisions concerning a more or less intensive local production in the market's country must be made. Typically production arrangements for semi-knocked down or completely knocked-down kits' (SKD or CKD kits) in the automotive or computer / electronics industries are used as means of entering new (or protected) markets (Moran 2000; Tulder and Ruigrok 1997; Elkin 2006). For instance the colour TV assembly in India since the mid 1980s (Kinra 1995), and the Information and Communication Technology (ICT) products manufactured in China in the 1990s (Hong 2008; Tan 2002). Other more popular examples come from the automotive industry: Japan, since the beginning of World War II (Smitka 1990), South Korea, in the early 1960s (Mukherjee and Sastry 1996) or more recently the motorcycle production in Vietnam in 1998 (Fukase and Martin 1999) and the production of Audi A 6 in Audi's joint venture with First Automobile Works (FAW) in Changchun, China in 2003 (Wagnera and Johnson 2004).

The dynamic learning and the accumulation of production experience in an "infant industry" environment can lead to fully competitive local industries over time. From the export of completely finished products to the completely local production, there are several strategies like CKD that equal in some properties and differ in others (Chung 1998). The strategies and terms for the strategies we apply and present in the following section are commonly used in science and industry (Volpato 2002). To distinguish these strategies from general supply strategies we introduce a special term in the following section.

2.1. Considered strategies

We call the following five supply strategies "supply strategies to enter developing markets" if they are applied to a supplier-customer relationship between a mother company in an industrialized country and a dealer within a developing market of a foreign country.

2.1.1. Completely build up (CBU)

CBU is the abbreviation for Completely Build-up Units, or also known as Fully Build-up Units (FBU) or BUX (Built-Up Export). It refers to the import or export of finished products.

The CBU process is the export of the finished products. The products are fully produced and assembled in the country of origin and exported as a whole piece to the destination market. Dealers or end consumers pick up the products directly from the importer.

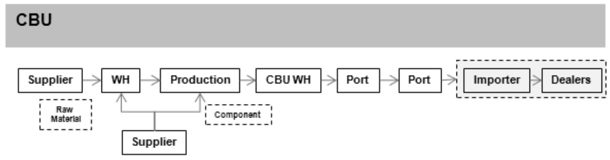

Figure 1: CBU Process Description

2.1.2. Semi Knocked Down (SKD)

Semi Knocked Down (SKD) is based on SKD lots or kits also known as SKD sets. A SKD kit needs the final assembly process to become a complete product (Jun 1987).

That is why in some literature SKD is also called turn screw assembly, by which only a certain module (for example wheels, steering wheels, and bumper) needs to be completely screwed or installed (Kaltofem 1999).

The SKD process can be divided into different variants we name SKD-Basic, SKD-Medium, and SKD-Advanced. All these SKD variants follow the same idea that the exporter collects and packs the parts in the SKD warehouse, while the importer repacks the products in the local OEM factory (SKD-packing and SKD-unpacking). The strategies differ on the exporter side, where the suppliers may provide the export factory with different assembly levels of components.

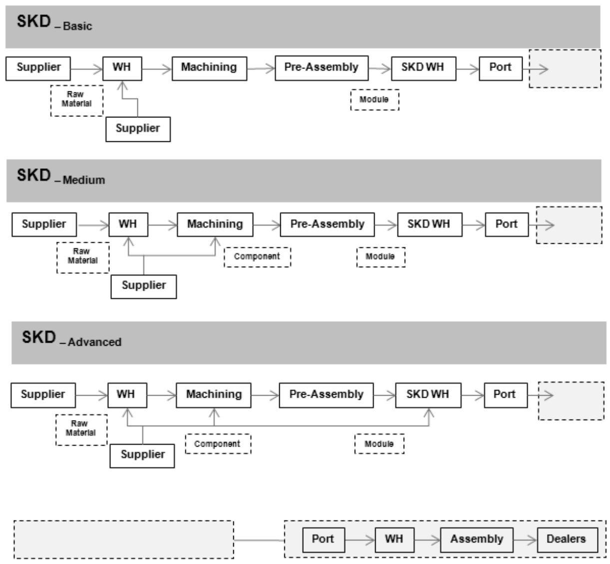

Figure 2: SKD Process Description

2.1.3. Completely Knocked Down (CKD)

Completely Knocked Down (CKD) is based on CKD lots or kits also known as CKD sets. CKD means the product is exported in parts and will be assembled at its destination (Schmitt, Thiesse and Fleisch 2007). CKD sets are managed in the same way as SKD. A CKD kit differs from a SKD kit in that it has less preassembled parts (Jun 1987), which means in the case of CKD, local assembly activities are much more substantial than with SKD (Tulder and Ruigrok 1997).

Both CKD and SKD refer to the practices of selling knocked down kits to foreign affiliates in order to finish the assembly process due to the consideration of the quality or sophistication of the local suppliers (Grant and Gregory 1997). The benefits of this practice for the exporter include avoidance of high import taxes and/or receive tax preferences for providing local employment (Hong 2008).

The CKD process can be also divided into different variants we name CKD-Basic, CKD-Medium, and CKD-Advanced. The difference between the three variants mainly lies on the importers side, where the factory in the import country takes over more and more responsibilities, coordinating local suppliers and accordingly the planning and assembly in the local factory is more and more sophisticated.

In general, under the CKD mode, from the strategy point of view, the exporter has the control of technology know-how. No matter in which degree and form of CKD, the factory organization structure and information flow are still dominated by the exporter side. From the operation point of view in the exporter warehouse all CKD parts are subject to the CKD-packing in the CKD warehouse before export. In the importer plant, before the assembly, the CKD kits are subject to the CKD-unpacking according to the demands from the actual working stations.

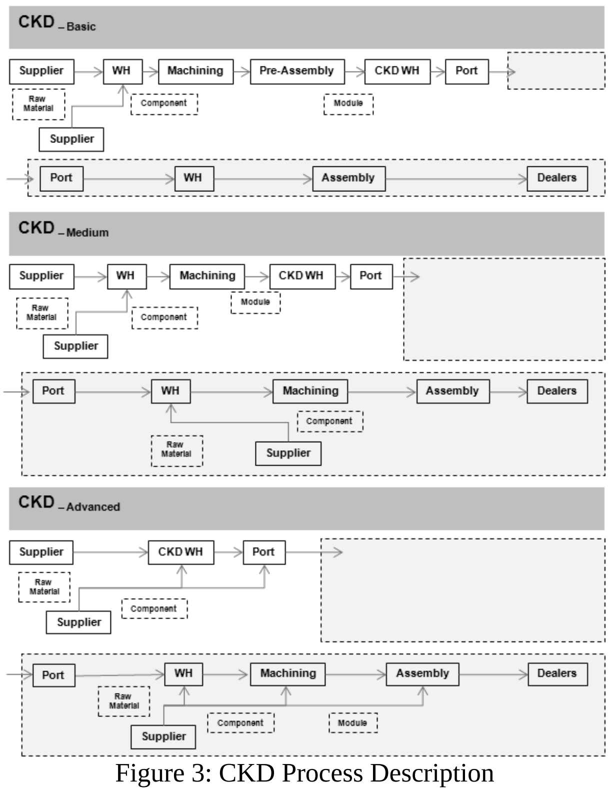

Figure 3: CKD Process Description

2.1.4. Part-by-Part (PbP)

PbP is the abbreviation of Part-by-Part. A PbP component shipment is normally delivered to a more sophisticated assembler who even can have full control of its bill of material and a high local sourcing. Under the mode of PbP, the shipment lines (part numbers and quantities) are not constant and generally not in engineered pack solutions.

Under the PbP mode, the importer takes over the control of technology know-how. The factory organization structure and information flow are also dominated by the importer side. The importer factory makes out the planning for the orders and transfers the information to the exporter accordingly, while the exporter acts as the coordinator for parts collection in between.

Besides, during the warehousing operation in the exporter PbP warehouse there is no repeated unpacking and packing for the PbP parts, which means in the warehouse for PbP only consolidation for the sea shipping has to be performed. When using PbP the decision has to be taken which parts can be delivered directly by the supplier and which are to be consolidated with others.

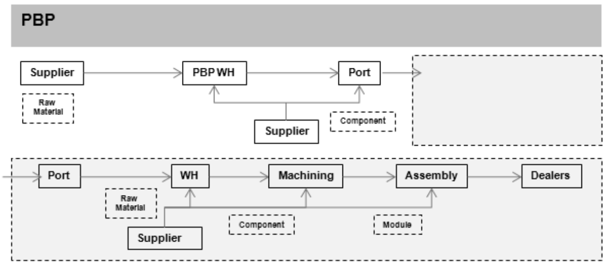

Figure 4: PbP Process Description

2.1.5. Mainly Locally Sourced

100% localized purchasing and production is quite rare, hence here we define a production as mainly locally sourced when the local contents account for more than 90%. Under this mode, the importer factory functions as the mother factory, fully independent in planning and production for the local market, only a limited number of parts will be ordered and transported from certain overseas suppliers.

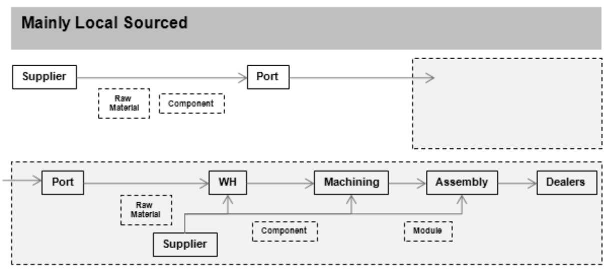

Figure 5: Mainly Local Sourced Process Description

2.2. Chronological order of the supply strategies

The five strategies described above can be related to the growth of sales of the product (product life cycle) and the market's maturity. This leads to a chronological order of the strategies (Figure 6).

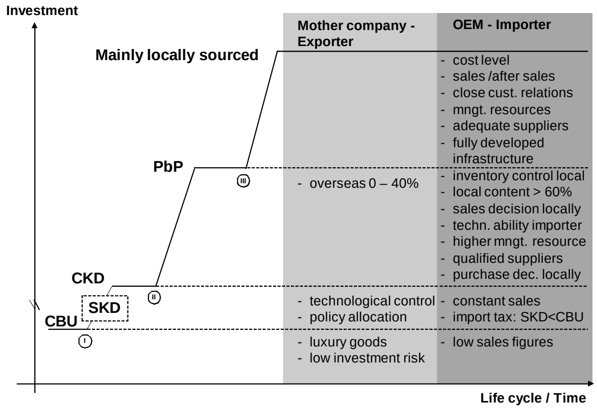

Figure 6: Chronological order of the Strategies

Following this order the mother company in the industrialized country might begin with a CBU strategy assuming that the sales are low and the infrastructure in the target country is poorly developed. Thus avoiding the risk of high investments in building-up own manufacturing infrastructure, supplying the dealer with completely build-up products is more feasible even if the import taxes might be higher.

When the sales increase and the maturity of the market grows it will become more feasible risking an investment and avoiding import taxes. Yet local suppliers are rare, leading to the strategy of SKD or CKD.

With even higher rising sales and established local suppliers avoiding packaging and repackaging of the CKD process becomes possible. The import OEM might even have developed the required know-how to run the planning mainly by itself, avoiding unnecessary high stocks or stock shortages. This leads to the PbP strategy.

The last stage would be reached if the pool of local suppliers is developed so far that a mainly locally sourced production strategy can be executed.

Taking this sequence into account, the main problem that remains is: "When exactly to shift from one strategy to another?"

3. STEP 1: STRATEGY SELECTION VIA TYPOLOGY

In this chapter we will provide a classification of characterising attributes and describe how a typology of the supply strategies to enter developing markets can be used to help a decision maker. However, the description of the actual typology would stretch the point of this paper and thus will be presented in another publication (Sieben et al. 2008). The usage of this typology is the first step of the strategy selection.

3.1. Using a typology

Since the process of selecting an appropriate supply strategy can be characterised as rather complex, from a system oriented point of view typification seems to be an especially suitable way to encapsulate those multiple aspects in a structured and consistent way and hence to provide a decision maker with an omnibus, decision relevant model (Kluge 2000; Elman 2004; Schieferdecker 2003).

	Criteria	Characteristics				
Hard lines	Local Market Trend for this product	Development	Introduction	Fast Growth	Stable Growth	Maturity
Hard lines	Local Policy on FDI in this industry	Strong local industry protection policy	JV with major share by local partner	JV with major foreign share allowed	100% foreign share allowed	
Hard lines	Local Policy on local content ratio	No local content	0-19%	20-40%	41-60%	>60%
Hard lines	Import Tax in importer OEM country	0	1 -15%	16 - 30%	31 - 50%	> 51%
Hard lines	Labour costs in OEM country	Lower than export country	No big difference	Higher than export country		
Hard lines	Local transportation costs in OEM country	Lower than export country	No big difference as the export country	Higher than export country		
Hard lines	Sea transportation price export from OEM country	Cheaper	More expensive	No big difference as import		
Hard lines	Sea transportation price import to OEM country	Cheaper	More expensive	No big difference as import		
Strategy Level	Product Life Cycle in OEM country	Development	Introduction	Fast Growth	Stable Growth	Maturity
Strategy Level	Real Market Demands for this product	Development	Introduction	Fast Growth	Stable Growth	Maturity
Strategy Level	Factory Organization	Controlled by Mother Company	Controlled by exporter OEM	Controlled by importer OEM		
Strategy Level	Techonology controlled by	Mother Company	Exporter OEM	Importer OEM		
Strategy Level	Target Market for the finished products	Only domestic consumption	Domestic and export			
Operation Level	Order from importer	Daily basis	Weekly basis	Monthly basis		
Operation Level	Packaging from exporter	product oriented	module oriented	component oriented	raw materials	
Operation Level	Warehousing before export	Consolidation	No Consolidation			
Operation Level	Shipping and Quality when damage occurs	Special order	no Special order			
Operation Level	Complexity (assembly / production) in OEM country	Not complex at all	Low	Medium	High	
Operation Level	Local content ratio in OEM production	0	0 - 40%	40 - 60%	60 - 90%	> 90%
Operation Level	Integrated Logistics Chain Control	Central Control by Mother Company	Decentralised controlled	Centralised control by OEM		
Operation Level	Inventory Transparency in OEM	No transparency when controlled by the mother	No transparency when controlled	Transparent when controlled by OEM itself		

Figure 7: Morphology of supply strategies to enter developing markets

From a typology, a type can be derived which represents a (possible) observation with common distinguishing features and attributes (properties). The five strategies described in chapter 2 can be considered as basic types within a typology. Every typology is based on a morphology (see: Figure 7) that consists of a list of characterising attributes and their potential settings. The different combinations of settings then lead to the possible types (here: strategies).

A decision maker can use the typology to get the appropriate strategy for the current supply situation by choosing settings for the different attributes. Since there are attributes unchangeable by the decision maker and attributes that can be influenced such as those which refer to strategic and those which refer to operational decisions, we have come up with a classification of these attributes, which will be presented in section 3.2. Hence there is also the possibility that the decision maker doesn't know or care about a setting for a certain attribute, this could lead to optimisation potential, when several of these "gaps" make more than one strategy possible. When these optimisation potentials exist they will be taken into the second step of our method and included into the selection of the optimal strategy via simulation.

3.2. Classification of the strategies' attributes

Here the classification will be described, identifying and classifying attributes of the strategies. In general we order the attributes into three main categories, they are:

- Hard lines
- Operation Level
- Strategy Level

In the following we will develop these three categories in detail.

3.2.1. Hard lines

The hard lines refer to economic conditions and industrial policy in the exporting country and / or importing country, which are hard facts and cannot be changed by business entities, including:

- Local Market Trend for this product
- Local Policy on FDI in this industry
- Local Policy on local content ratio
- Import Tax in importer OEM country
- Labour costs in OEM country
- Local transportation costs in OEM country
- Sea transportation price export from OEM country
- Sea transportation price import to OEM country

3.2.2. Operation Level

The operation level indicates the business environment for the supply process, factory or products in the importing or exporting country, which can be either defined by the local market situation or decided locally in the factory, for example:

- Product life cycle in OEM country
- Real Market Demands for this product
- Factory Organization
- Technology control party
- Target Market for the finished products

3.2.3. Strategy Level

The strategy level mainly contains decisions from the overseas mother company, for example:

- Order from importer
- Packaging from exporter
- Warehousing before export
- Shipping and Quality when damage occurs
- Complexity (assembly / production) in OEM country
- Local content ratio in OEM production
- Integrated Logistics Chain Control
- Inventory Transparency in OEM

4. STEP 2: SIMULATION

After the typology has been applied to a certain supply situation, a subset of the strategies has been selected due to political and strategic parameters, yet only roughly focussing on the process parameters themselves. This focus will now be set using the process simulation. The parameter setting from the typology will be extended by more precise settings and additional parameters needed for the simulation model. Each member of the subset of strategies is then integrated in the basic model, forming distinct scenarios that are simulated, analysed, compared and evaluated with respect to the process parameters. The best strategy can then be selected and applied. In the following sections the simulations environment used to perform the second step of the method and the components that can be used to model the supply scenarios are presented.

4.1. The OTD-NET simulation environment

OTD-NET is a simulation and modelling environment using discrete-event simulation to analyze the order-to-delivery process of huge supply networks. It was developed by the OTD-group in the Fraunhofer Institute for Material Flow and Logistics in Dortmund, Germany.

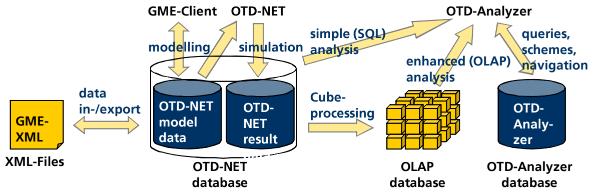

Figure 8: The OTD-NET environment

Figure 8 shows the three modules of the environment: the Graphical Modelling Environment (GME), the Simulator and the Analyzer. Using these three components OTD-NET can be used to model and simulate supply networks based on customer orders or forecasts that are back-propagated through the supply chain. Considering realistic network planning, single orders are satisfied with single products which can be observed throughout the whole process. Economical ratios as capacities, workload, stocks, delivery reliability, process times and costs or capital commitment can be derived and evaluated.

Regarding supply strategies to enter developing markets, OTD-NET can be used to model, analyze and compare different strategies, focusing on ratios such as stocks, transport/ packing costs and capital commitment.

4.2. The components of the process model

To create a process model of a global supply chain, the OTD-NET environment offers several components and options that can be divided into three mayor categories. These components can be combined and set differently according to the focus of the scenario to be modelled.

4.2.1. The network components

The main component of the network is the plant of the original equipment manufacturer (OEM) in either the industrialized or the emerging market's country. This component is defined by the location, capacities, working shifts, lead time, products and the behaviour of the product sequencing. The production sites of the suppliers of the OEM are connected via distribution channels, delivering the parts the main products consist of. These production components have mainly the same attributes as the OEM plant, but can additionally be run as Build-to-Order or Build-to-Stock suppliers. The distribution channels that connect the suppliers with each others or the OEM can use all kinds of transportation devices (trucks, trains, ships, aeroplanes, etc.). They have a capacity, transportation behaviour (either by plan or on demand) and are connected by conditioned routings. In between the distribution channels can be warehouses with capacities.

4.2.2. The product structure

The product structure is a hierarchy with the end products to be sold to the customers at the top. These products have different property groups leading to different variants of a product. Properties consist of parts that can consist of parts themselves, forming a hierarchical bill of material. Parts and properties are produced by the suppliers while the products are manufactured by the plants. Complex dependencies between the properties can be included leading to constraints and restraints between the properties of a product.

4.2.3. Sales planning and customer behaviour

The production in OTD-NET is triggered by customer orders and forecasts. The plant generally produces based on periodic forecasts, propagating the demands back through the network. Producing on forecast can lead to a gap between the products built and the products wanted by the customers. This gap can be used to model the deviation between the forecasted and the actual demand. The customers in the model can be patient, waiting several time periods for their products, or buying products similar to the one originally wanted if there is a certain discount. Furthermore they could not be willing to accept products that are more than a certain time period in the warehouse. Thus, a complex behaviour of customers and planning cycles can be realised.

5. THE SCENARIO

5.1. Description

The scenario we apply the method to is a global supply scenario within the automotive industry. It involves typical processes of global supply chains and focuses on the entry of an emerging market. Furthermore a single strategy cannot be clearly derived. Thus the scenario is appropriate for demonstrating our concept.

In detail a German car manufacturer is selling a certain car in China. Transportation between the continents is done via shipments taking 6 weeks, debarking weekly. Focusing on the second step of the method, we assume that the first step, applying the typology, has yield in a subset of two strategies. Since an assembly plant in China already exists these strategies are CKD – including CKD-packing of all parts of one car into one 40ft container in Germany and CKD-unpacking of this container in China to feed the different lines – and PbP, which in this case means the German suppliers send their parts directly to China. The decision to be made is if it is feasible to consolidate the parts in a CKD-set or if it is better to send them unconsolidated, saving process costs. In Figure 9 you can see the two different supply strategies.

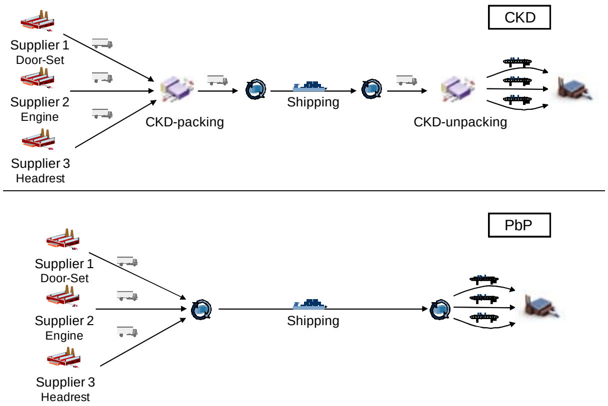

Figure 9: Network structure of the scenario

The scenario contains three suppliers, supplying three parts for the car that have been selected for their size and values. The door-set, supplied by Supplier 1, is the biggest part and has a medium value. Supplier 2 provides the engine with a medium size and a high value, and Supplier 3 the headrests with a small size and small prize. Thus, we can analyse different behaviour towards warehousing costs, expenses for capital commitment and number of parts per 40 ft container of the three parts.

Comparing the two strategies, one can find that in the case of CKD all parts for one car are delivered in one container, leading to a minimal stock in both countries, since exactly the needed amount of parts can be delivered. But the additional costs for CKD-packing and CKD-unpacking have to be taken into account. Considering the other strategy, PbP, these extra costs are obsolete, but since every part is sent separately, a 40 ft container full of part x includes parts for n cars, depending on the size of the part. We assume that sending half filled containers is not feasible at all considering the disproportionally high transportation costs of 1500$ per container. Hence it could happen that, depending on the sales, one container contains parts for more cars than the amount built in one week. This holds especially true, when the transport frequencies are adaptable since applying the transport frequency needed to fill whole containers of smaller parts yields in higher stocks. Thus, on the one hand parts have to be pre-produced in Germany, on the other stored in China until they are needed. Figure 10 shows the stock behaviour of the two strategies.

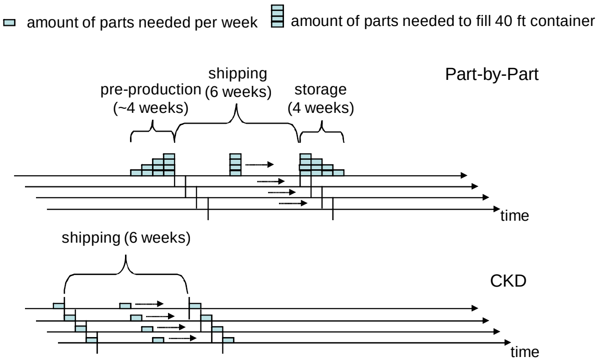

Figure 10: Principal behaviour of the stocks in both strategies

Since the amount needed per week is equal to one unit, but the amount of a certain part to fill one container is four units, the supplier of that certain part, using PbP, has to pre-produce for four weeks, thus sending parts to China only one time a month. Using CKD complete kits are sent, each filling one container, so that the total amount can be divided into four deliveries leading to a minimal stock.

The scenario is now divided into two parts. First of all we will decide which is the most suitable – that is economic – strategy for a certain sales figure by comparing the simulation results for both strategies. Secondly, to point out that selecting different strategies according to the heights of sales makes sense and the re-design process is necessary, we are going to change the sales, to find the point were switching the strategy becomes feasible.

So the questions to be answered are: “Which strategy is more feasible regarding a certain sales figure?”, “How many $ could then be saved per part?” and “At what amount of sales per month is it feasible to deliver a certain part directly to China (using PbP), when considering dynamic system behaviour?”

To find an answer to these questions we will model the two strategies using the OTD-NET environment, apply simulation and calculate the total cost for both cases.

$$C_{PbP} = \mathrm{cstock}(\textit{"germany"}) + \mathrm{cclr}(\textit{"germany"}) + \mathrm{cshp} + \mathrm{cclr}(\textit{"china"}) + \mathrm{cstock}(\textit{"china"}) \tag{1}$$

$$C_{CKD} = \mathrm{cstock}(\textit{"germany"}) + \mathrm{cwh}(\textit{"germany"}) + \mathrm{cclr}(\textit{"germany"}) + \mathrm{cshp} + \mathrm{cclr}(\textit{"china"}) + \mathrm{cwh}(\textit{"germany"}) + \mathrm{cstock}(\textit{"china"}) \tag{2}$$

The total costs for the PbP strategy (1) consist of the costs for stock in Germany (3), the costs for customer clearance in Germany (6), the shipping costs (7), the costs for customer clearance (6) in China and the costs for the stock at the factory in China (3).

$$\mathrm{cstock}(\mathit{country}) = \sum_{\mathit{part}} \mathrm{chold}(\mathit{part}, \mathit{country}) + \mathrm{crent}(\mathit{country}) \tag{3}$$

$$\mathrm{chold}(\mathit{part}, \mathit{country}) = \mathrm{avgstock}(\mathit{part}, \mathit{country}) \cdot \mathrm{val}(\mathit{part}) \cdot \mathrm{irate}(\mathit{country}) \tag{4}$$

$$\mathrm{crent}(\mathit{country}) = \max_t \Big(\sum_{\mathit{part}} \mathrm{stock}(\mathit{part}, t, \mathit{country}) \cdot \mathrm{size}(\mathit{part})\Big) \cdot \mathrm{rentsqm}(\mathit{country}) \tag{5}$$

The costs for the stock in a country are the sum of the holding costs of all parts (4) plus the rent for the warehouse (5) calculated based on the maximal space needed.

$$\mathrm{cclr}(\mathit{country}) = \#\mathit{ships} \cdot \mathrm{clrtaxe}(\mathit{country}) \tag{6}$$

The customer clearance is a tax paid per ship (6).

$$\mathrm{cshp} = \#\mathit{container} \cdot \mathit{containerfee} \tag{7}$$

The costs for the sea transportation (7) are paid per 40 ft container.

The total costs for the CKD strategy (2) are equal to the costs for the PbP strategy except for the additional costs for the CKD-packing and CKD-unpacking – that is the warehousing in Germany (8) and the warehousing in China (8).

$$\mathrm{cwh}(\mathit{country}) = \#\mathit{container} \cdot \mathrm{cpacking}(\mathit{country}) + \sum_{\mathit{part}} \mathrm{chold}(\mathit{part}, \mathit{country}) + \mathrm{crent}(\mathit{country}) \tag{8}$$

The warehousing costs are the sum of the salaries paid for the packing of the containers, the holding costs (4) and the rent for the warehouse (5).

Now that the scenario and the cost functions have been described, the results will be presented in the next section.

5.2. Results

We assume that applying the first step of the method – the typology-based pre-selection – to the scenario described above has yield that two of the strategies to enter developing markets – CKD or PbP in this case – are possible candidates to apply, while the others were already filtered out. Now that there are only two candidates left we apply the second step using simulation to get to the final decision.

As stated in the chapter above three questions to be answered via simulation are: “Which strategy is more feasible regarding a certain sales figure?”, “How many $ could then be saved per part?” and “At what amount of sales per month is it feasible to deliver a certain part directly to China (thus using PbP), when considering dynamic system behaviour?”

To get an answer to the first question the cost function presented in chapter 5.1 is evaluated for the simulation results of both scenarios. A basic sales figure is used for this comparison (Figure 11).

As you can see the amount of products demanded in the whole year for the basic scenario is 4380, which may indicate an early phase of the life cycle.

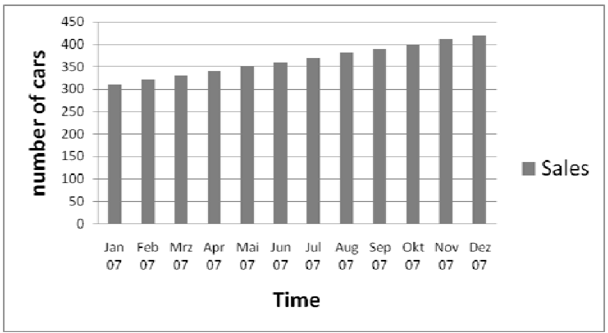

Figure 11: Sales per Month (basic scenario)

Comparing the simulation results of the two scenarios, we made some observations. First of all the cost for the shipping exceed the other costs 7 times (Figure 12) – which confirms our assumptions, that the examination of sending containers that are not completely filled, is unnecessary.

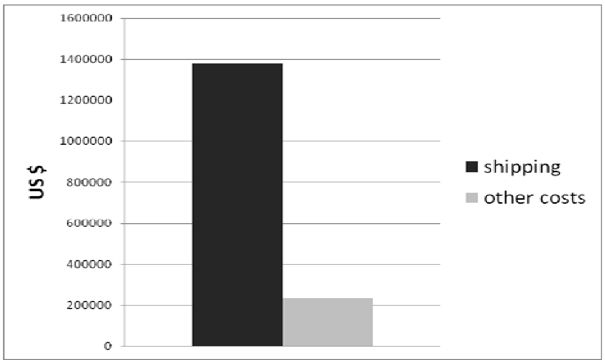

Figure 12: Comparison of shipping costs and remaining costs

Secondly the distribution of the cost of both strategies differ strongly form each other. Figure 13 shows the distribution for the basic sales scenario of the CKD-strategy.

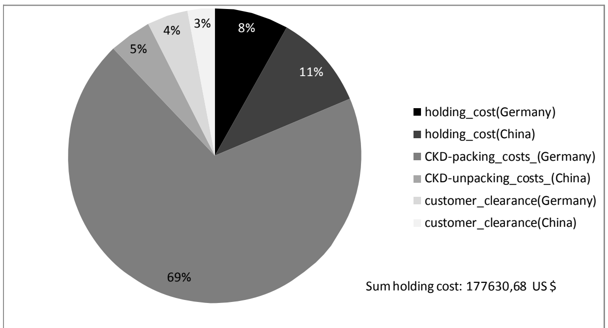

Figure 13: Cost distribution for the CKD-strategy

The costs for the repackaging in Germany exceed the costs in China, which is due to the higher salaries for the warehouse personal. The holding costs are relatively low for this strategy, since only the parts for the production program for one week are stored.

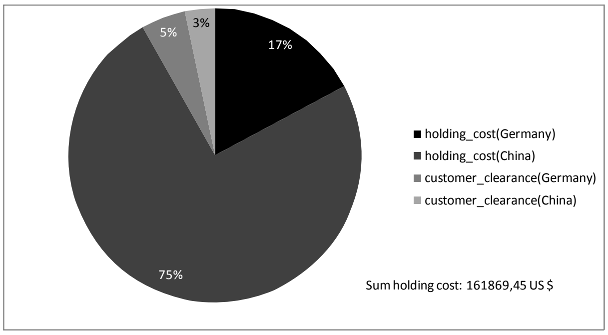

Figure 14: Cost distribution for the PbP-strategy

Figure 14 shows the cost distribution for the PbP-strategy. Compared to the CKD-strategy one can see that storing the parts is the primary cost factor, which confirms the assumptions made in chapter 5 about the indispensability of preproduction in Germany and storing in China.

To answer the first question the comparison of the total costs for both scenarios yield that at this phase the CKD-strategy is the cheaper one. The actual amount of money that can be saved selecting the right strategy can be obtained from the simulation results as well. For this scenario it is a maximum of 23 US $ per product, that is 23 US $ times 4380 products = 100740 US $ for the basic sales scenario.

To answer the last question, which is the right point in the life cycle (that is: the amount of sales reached) to change the strategies, we applied different sales figures to both scenarios. These figures were created by multiplying the basic figure with several different values. The results were as follows.

On the one hand, regarding the CKD-strategy, the distribution of the costs doesn't differ much for the different sales figures. This can be comprehended taking into account that for this strategy the costs are directly linked to the amount of products ordered, since every product has a single container. On the other hand the costs for the PbP-strategy differ plainly. In Figure 15 the holding costs are broken down to the single parts for the PbP Strategy and two sales scenarios.

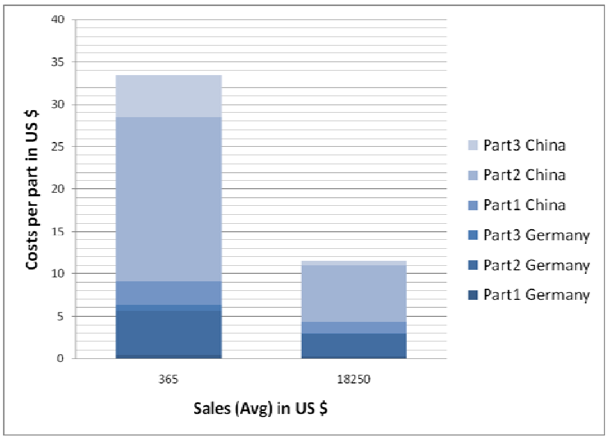

Figure 15: Holding costs per part for two sale figures

In Figure 15 it can be observed that the highest costs have to be allocated for part 2, the engine, which also has the highest value. Nevertheless, when focussing on the proportional amount of money that can be saved per part, increasing the sales of part 3, the headrest, is the most promising option. While the seat's and engine's costs are decreased by 40 % the headrest's costs can be decreased by 90%. That is because the amount of parts that fit in one 40 ft container is much higher for part 3 than for the other two. Hence a container filling for the other two parts lasts a shorter period of time and thus fewer parts must be stored at both sides of the supply process. Therefore the possible amount of money that can be saved through increasing the sales is far higher for part 3, since the other two parts are already transported optimally.

Now that the possibilities to save holding costs by increasing the sales using the PbP-strategy have be illustrated, the comparison of both strategies regarding the total costs for different sales will be shown. Figure 16 presents this comparison.

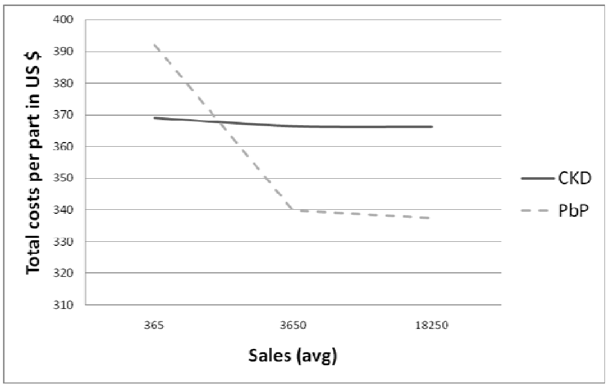

Figure 16: Comparison of the total costs for both strategies and different sales

The costs of the CKD-strategy are more or less constant for different sales, while the costs of the PbP-strategy decrease with the sales. Thus when the sales are low (e.g. at the beginning of a product life cycle) the CKD-strategy is cheaper since the holding costs are minimized. However, at a certain amount of sales it is more feasible to switch to the PbP-strategy (only considering the process point of view). That is because of the saved process cost for the omission of the consolidation on the one hand, and for the decreasing holding cost due to the rising sales on the other hand.

It has been exemplarily shown that this strategy switching point in the life cycle can be named using simulation and that the actual money saved can be numbered. Furthermore, it has been indicated that simulation can be used to rate different supply strategies with respect to the aspect of consolidation of parts. An optimisation of the process costs can be obtained by deciding for single parts depending on their value and size if a consolidation makes sense or not. Additionally, the whole process and the process costs can be made transparent to the decision maker through modelling and simulation.

6. RESULTS AND OUTLOOK

We started identifying the supply strategies to enter developing markets and outlined a method for the strategic re-design in this application domain. A morphology was presented classifying the strategies and building the basis of a typology that will be presented shortly. Built upon this typology driven pre-selection a simulation-based comparison was presented focussing on the process parameter. The method was validated with a scenario focussing on the process cost of transportation and warehousing of either CKD or PbP. Not only the concrete costs could be named but it could be shown that switching the strategy when comparing different sales figures can save money. The results also show that a focus of further work in this sector should concentrate on minimising the amounts of containers used, since this is the main cost factor. Furthermore other aspects of the process must be taken into account such as:

- applying more fluctuating sales figures
- cost for extra transportation due to lost or damaged goods
- stock heights due to planning inaccuracies comparing planning control by the exporter or the importer

Beyond this special comparison the other strategies have to be taken into account as well. Thus further research will on the one hand include proofs of the concepts for the other strategy comparison and on the other hand include the permanent testing and extending of the typology.

Moreover the application of the method in the industry integrated into a decision support system will be aimed at.

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