Applying hybrid system theory to supply chain design

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ABSTRACT
Supply Chain Management delivers a considerable amount of ideas and methods to design the value stream. Each of these concepts may lead to significant cost reduction and higher service levels. But the same concept does not work for different customers and their diverse needs. Thus, a “one size fits it all” supply chain cannot lead to success. The key to overcome this obstacle is the hybrid supply chain. This paper outlines the application of hybrid system theory to supply chains. After a comprehensive overview of existing methods for the design of supply chains is given, a methodology for a customer-to-customer oriented supply chain design is presented. This approach adopts the hybrid system theory to supply chains which is in a nutshell that hybrid systems use the advantages of its subsystems to reach a superior result to one system alone. Concluding a case study illustrates the application of the methodology.
I. INTRODUCTION

In modern business, satisfying customer needs is a strategic factor of success. Nevertheless, many companies are incapable of fulfilling logistic services as they are required by the market. In consumer goods industry for instance, this deficiency results in out-of-stock-situations and high sales losses (GRÜN et al. 2002, p. 7ff). Insufficient availability of goods, at the point-of-sale or in any stage of the supply chain, is caused by inadequate service levels of the suppliers, inaccurate forecasting, lack of information exchange and unpredictable ordering behaviour of suppliers (BUNDESVEREINIGUNG LOGISTIK 2005, p. 99).

However, the underlying reason for insufficient availability of goods is best described by an antagonism between the desire to minimize supply chain costs by raising efficiency, and the wish to maximize availability by increasing the agility of the supply chain. This can be derived from the diverging goals of the entities and members of the supply chain: Whereas demand-orientated, customer-focused entities focus on high flexibility, short delivery-time and high availability, supply-side oriented entities value primarily the minimization of production-, transport-, purchasing- and inventory costs (STRATTON/WARBURTON 2003, p. 184). Diverging goals may exist even in a single company (e.g. between sales, procurement and production departments) and are prevalent between different companies that are working together in a supply chain. The antagonism between demand- and supply-side counterparts of a supply chain leads to significant logistical deficits.
Although this antagonism is a persistent issue in praxis, to date neither industry nor science has found adequate approaches to resolve this dilemma. Existing approaches try to solve the problem either by implementing a more efficient asset management, or by introducing more effective process design. They failed, for they lack any holistic contemplation of the entire supply chain (WILDEMANN 2009, p. 1ff). Since hitherto existing approaches themselves are focused either on the demand- or supply-side, they are unable to cover the above mentioned antagonism (GOLDSBY et al. 2006, pp. 57ff). As an example, Just-in-time strategies (WOMACK/JONES 2004, p. 161) address only production- or supply-oriented parts of a supply chain, while both Efficient Consumer Response (ECR) or Category Management (CM) (MAU 2003, p. 22ff) intend to optimize the interface between customer and manufacturer. As a result, supply chains are often managed in a contradicting way – both in terms of sales activities and taking into account production and procurement goals (cp. Fig. 1). Failure of the value stream, out-of-stocks and revenue losses are the outcome.

Fig. 1: Diverging goals in the supply chain
To solve this dilemma, an end-to-end orientation towards the customer is required. In terms of the marketing perspective, the extension and diversification of the assortment of goods is understood by striving for a higher customer orientation (STEPHAN 2007, p. 3). Reverse, this is also valid for a specification of the supply chain itself. The first step, a different design of supply chains in different branches, is already implemented in many industrial segments, e.g. Fast Moving Consumer Goods (FMCG) Industry is focusing on optimising their distribution, whereas Automotive Industry continuously increases the integration of their suppliers. But only very few companies have recognized that a diversification of the supply chain within one single branch of business does not only lead to further reduced costs (ATKEARNEY 2004, p. 1), but will solve the described antagonism between demand- and supply-side. Executive managers in modern industry therefore have to take a two-fold decision: Which type of supply chain is suitable for their customer needs, and how many supply chains are necessary, yet affordable under economic reasons (cp. Fig. 2).

II. ESTABLISHED APPROACHES FOR SUPPLY CHAIN DESIGN

As a first approach, Fisher (FISHER 1997, p.106ff) contrasts different types of goods and their associated demand predictabilities with their respective supply chains. On the basis of
two generic product types – functional products with high demand predictability and long life-cycles (e.g. diapers) and innovative products with low demand predictability and short life-cycles (e.g. cellular phones) respectively – he defines two corresponding supply chain types to meet the distinct requirements of these product types. For functional products, the primary goal of supply chain design is cost reduction with respect to predictability and reliability. In contrast, innovative products require supply chains that are designed to minimize the lead time between order and delivery. According to Fisher, these requirements result in two distinct types of supply chains, which he names “Efficient Supply Chain” and “Responsive Supply Chain” (FISHER 1997, p.106ff; ALICKE 2005, p. 144; CHILDERHOUSE/TOWILL 2006, p. 361f).

Christopher, Towill and Mason-Jones, based on Fisher’s suggestion, propose the “Lean Supply Chain”, “Agile Supply Chain” and “Leagile Supply Chain” (MASON-JONES et al. 2000, p. 4061ff; CHRISTOPHER/TOWILL 2001, p. 5; AITKEN et al. 2005, p. 75f). While the Lean Supply Chain focuses on cost reduction for standardized mass-products, the Agile Supply Chain aims for high availability of goods and short lead times. Both supply chain types are similar to the ones described by Fisher, while the Leagile Supply Chain is an extension of the two former types (MASON-JONES et al. 2000, p. 4061ff). It is defined as a combination of Lean and Agile Supply Chains by different authors, introducing a point-of-decoupling (OLHAGER 2003, p. 319ff) to separate Lean (upstream) from Agile (downstream) processes. Extended by Christopher and Towill to what they call “hybrid strategies”, this approach is able to model parallel processes (Lean and Agile) in a single supply chain.

All approaches that were introduced to this point are focused on the demand-side of the supply chain. They become extended to the supply-side by Lee (LEE 2002, p. 93ff), who
considers a distinction between stable and evolving supply processes. Stable processes are characterized by fully developed technologies and manufacturing techniques, as well as by a reliable procurement market. On the contrary, an evolving process is not fully developed and becomes subject to permanent change, its procurement market is limited relating to volume and experience. Considering the supply-side, Lee yields a “Risk-Hedging” and an “Agile” supply chain in addition to Fisher’s Efficient and Responsive supply chains. The former is capable of pooling and sharing capacities and resources, e.g. different companies save storage cost by pooling their stocks of certain critical goods. The Agile Supply Chain is defined according to Christopher’s Towill’s and Mason-Jones’ Leagile Supply Chain, namely as a combination of the Responsive and the Risk-Hedging type.

Corsten and Gabriel (CORSTEN/GABRIEL 2004, p. 245) propose another attempt to extend Fisher’s approach, without taking Lee’s approach into account. They define four supply chain strategies – a lean supply chain, a flexible supply chain, a fast supply chain and an aligned supply chain. The first three types match the Lean, Leagile and Agile supply chains of Christopher, Towill and Mason-Jones, but the aligned supply chain represents a true extension of the concept. Designed for efficiency, the aligned supply chain is focusing on the optimization of internal processes, unlike the lean supply chain, which tries to further integrate suppliers into the supply chain process.

Childerhouse and Towill summarize all depicted approaches for supply chain modelling as “market-oriented supply chains” (CHILDERHOUSE/TOWILL 2006, p. 357ff). On the basis of Christopher and Towill (CHRISTOPHER/TOWILL 2001, p. 235ff), they establish a “migratory model” to describe supply chain development. This model subdivides four distinct phases, a “product oriented push”, “market oriented push”, “aggregate market pull” and “individual consumer pull”. While Childerhouse and Towill define a high scale of integration
as a desirable goal in migratory models in general, no such goal exists with respect to market orientation. Instead, the desirable goal is to meet the requirements of market and customer completely. Supply chain segmentation and the design of parallel, segment-specific supply chains according to customer and market needs is the adequate means to achieve this goal (SCHNETZLER et al. 2006, p. 1ff).

III. SUPPLY CHAIN SEGMENTATION

Individualization of customer needs and subsequently the individualization of production and of supply chains themselves is a 21st-century-phenomenon (CHILDERHOUSE/TOWILL 2006, p. 357ff, SCHMIDT et al. 2008, p. 841ff). To meet this challenge, a classification of supply chains, as well as precise knowledge of customer needs, is required. Comprehensive systems for classification of supply chains are necessary to find the appropriate answers to the questions “How many supply chains?” and “What kind of configuration?” (CHILDERHOUSE/TOWILL 2006, p. 357ff). However, current approaches offer basically just very generic support to companies that are trying to configure and improve their supply chains (SCHNETZLER et al. 2006, p. 1ff).

Originated in marketing, segmentation intends to increase the focus on the customer, while coping with the enhancement of complexity generated by the ongoing individualization of demands (SCHNETZLER et al. 2006, p. 4). Homogenous segments implemented in a supply chain allow customers to be addressed in a more distinguished way (BRUHN 2007, p. 58). Supply chain segmentation therefore proposes a “customer-to-customer orientation” and at the same time determines the number of required supply chains. The customer-to-customer orientation reflects the supply chain’s orientation towards the customer, whose different buying attitudes, individual expectations towards service and variable willingness to pay different prices (BARRATT 2004, p. 30ff) determine the end-to-end design of the supply
chain (cp. Fig. 3). Based on this individualized input, separated supply chain segments are formed and segment-specifed phenotypes are deduced, all to meet customers demands in the best possible way.

![Customer-to-Customer Orientation](image)

**Fig. 3: Customer-to-customer orientation in the supply chain**

### IV. IDENTIFYING HOMOGENOUS SUPPLY CHAIN SEGMENTS

Customer needs as well as the true customer characteristics must be analysed and categorized in order to identify the significant segments of a supply chain in a customer-to-customer sense. The deduction of these categories is based on certain attributes and their respective values (KNOBLICH 1969, p. 143), allowing for the classification of customer needs in the area of the conflict between agility vs. efficiency and the description of the true customer characteristics in terms of predictability.

To accurately describe the needs and expectations of the customer, a basis of criteria is given by the framework of “order qualifiers” and “order winners” proposed by Hill (HILL 2000, p. 50ff). While order qualifiers describe the fulfilment of requirements that are necessary to be competitive at all, order winners are criteria that make a difference between competing companies. In the sense of supply chain segmentation, different criteria may be identified as qualifiers or winners for different customers. Following, different criteria describing the customer needs can be deduced by means of the essential target objectives in
Supply chain management (cp. Fig. 4). Among these are, expected service levels, expected delivery reliability, expected lead time, expected flexibility, price expectations and consignment requirements. Categorization and description of these requirements can be achieved by defining their attributes and corresponding values.

![Supply Chain Performance Diagram](image)

**Fig. 4: SCM Target System (cp. MEYER, SANDER, 2007, p. 54ff)**

The definition of the customer’s characteristics may result on the basis of attributes that describe either past time relationship to the customer or are the result of an external analysis of a first-time customer, resulting in a re-configuration or an initial configuration of the supply chain respectively. Such attributes may be demand volatility, seasonality, impact of trends, information exchange, order-change behaviour and sourcing-strategies.

**V. SUPPLY CHAIN PHENOTYPES**

These attributes and their respective values are the basis for the supply chain segmentation. In combination, they yield a 4-fold matrix, whose quadrants represent the distinct segments of the supply chain that has to be designed. Each segment can be allocated to a distinct supply
chain phenotype, according to customer needs and characteristics: “cost-efficient”, “responsive”, “accurate” and “agile” (cp. Fig. 5).

Quadrant I and IV form a homogenous pattern with respect to customer needs and customer characteristics. A predictable behaviour of the customer allows high planning accuracy and therefore enables the most efficient design of the involved processes (quadrant I). Meeting the demands of unpredictably acting customers requires high agility (quadrant IV). In contrast, quadrants II and III describe a heterogeneous situation. The customer’s desire for an agile supply chain while acting predictable, requires the highest accuracy in the planning processes, to guarantee the required availability and flexibility (quadrant III). However, customers acting highly unpredictable, but demanding high cost efficiency, can only be satisfied by a highly responsive supply chain (quadrant II).

Fig. 5: Supply chain segments and supply chain phenotypes
VI. HYBRID SUPPLY CHAINS

Supply chain segmentation allows companies to classify their customers and allocate them to the four segments described above. The corresponding supply chain phenotypes constitute the initial point to adjust all supply chain activities. To supply customers according to their respective requirements, it is recommendable for companies to establish four supply chains, if their portfolio of customers is heterogeneous, or less if a more uniform type of portfolio is present. By this approach, all customers can be satisfied, while supply chain agility and efficiency are respected. Simultaneous operating of different supply chains, in which customers are being allocated accordantly, is therefore the next consequential step in supply chain management. The mentioned antagonism of a “one size fits all” approach and its divergent goals can be resolved by introducing the described approach which is called “hybrid supply chain”.

Fig. 6: Hybrid engine as an example of a hybrid system

The joint use of different supply chain phenotypes equates on the definition of a hybrid system (BROCKE 2004, p. 13f), for which a hybrid engine is an adequate analogy (cp. Fig. 6). The hybrid engine covers all the advantages of a single combustion engine (high moment of torque, high final speed, high cruising range) and an electric motor (zero-emission, both exhaust and noise) by simultaneously minimizing their disadvantages (emission and bad...
energy balance of combustion, low speed and low range of electric), thus reaching a far better performance than any of its subsystems alone. The deduced supply chain phenotypes constitute, in analogy to the subsystems of a hybrid engine, the different “devices” of a hybrid supply chain, that are employed according to well-defined rules and standards, that is to say, the segmentation.

**VIII. CASE STUDY**

In order to proof the practicability of the shown concept of hybrid supply chains, a short case study is illustrated. A company with more the 50,000 employees and subsidiaries in about 100 countries worldwide served different markets by a “one-size fits all”-supply chain. The different market segments across all business units are semiconductor, assembly, aerospace, construction, surface treatment, flexible packing, consumer goods, paper converting, coating, tobacco, automotive, steel and coil and metal packaging. Indeed, the supply chain performance did not meet the needs of the different market segments perfectly. The situation of the “one-size fits all”-supply chain lead to insufficient customer satisfaction, because their divers requirements had not been mapped to the supply chain. To resolve this obstacle, the company decided to implement the hybrid supply chain approach.

First, the company accomplished a comprehensive analysis of each customer’s needs and characteristics resulting in about 20 homogenous customer types across all business units. According to the identified needs and characteristics, each customer type, and by this means the corresponding customers, had been allocated to a supply chain segment in the described 4-fold Matrix (cp. Fig. 7).
In a second step, each of the supply chain phenotypes has been detailed by standard supply chain strategies. The “Cost-efficient Supply Chain” aims for highest capacity utilization in production and distribution to create the cost efficiencies in the supply chain. Therefore a combination of a make-to-order and make-to-forecast strategy has been applied. The “Responsive Supply Chain” pursues aggressive make-to-order strategies to be responsive and flexible to changing orders. The “Accurate Supply Chain” strives for optimized inventories by keeping the pipeline flowing to reduce the risks of supply short-ages. Thus, a pure make-to-stock strategy has been utilized. Finally, the Agile Supply Chain is carried out by a combination of make-to-order and make-to-(buffer) stock strategy to be responsive, while reducing the risks of supply short-ages.

In a third step, each supply chain phenotype has been aligned with distinct supply chain performance levels. The essential key performance indicators of the supply chain that are

Fig. 7: Allocation of the customer types to the supply chain segments
service level, reliability, order cycle time and flexibility and costs have been defined according to the customer needs and characteristics for each supply chain segment. Thereby, it is obvious that the “Agile Supply Chain” is subject to the highest performance level, whereas the “Responsive Supply Chain” leads to minimal supply chain costs.

By the application of the hybrid supply chain approach the company reach a major impact on the customer satisfaction as well as the diverging goals of the demand- and supply-side have been aligned.

VIII. CONCLUSION

To satisfy heterogeneous customer needs, “one size fits all” supply chains turn out to be neither effective nor efficient. The pictured antagonism between demand- and supply-side yields significant availability problems which in turn cause eminent sales losses. This conflict can be solved by an end-to-end orientation to the customer, while diversified requirements and characteristics can best be met by a segmented supply chain.

Any attempt to utilize such “hybrid” supply chains for industry will first have to further develop the approach of supply chain segmentation to substantiate the supply chain phenotypes. According to the SCOR-model (SUPPLY CHAIN COUNCIL 2006, p. 2; BOLSTORFF/ROSENBAUM 2003, p. 2) one has to allocate supply chain management concepts according to the requirements of the high level processes source, make and deliver in order to attain a detailed reference configuration for each supply chain phenotype.

It is the aim of current research, to develop the supply chain segmentation approach further and to build a framework for hybrid supply chains, in order to support executives in industry in answering the question of number and configuration of supply chains and to assist them to
overcome the conflict between the market- and production-oriented sides of the supply chain. Hybrid supply chains offer an efficient and likewise powerful way to face growing requirements and increasing dynamics of markets, as well as the individualization of customer needs. The final goal is therefore the extension of supply chain management by including hybrid supply chains.

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X. LITERATURE


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