Introducing supply chain segmentation procedures into flexibility management

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Abstract
Flexibility measures are an effective means to cope with a volatile business environment. This paper proposes a procedure for the identification of product-customer-segments and the application of appropriate flexibility measures, hence allowing for proper treatment of heterogeneous product-customer groups' requirements. The concept is evaluated using DES in an industrial scenario.

Keywords: Supply chain flexibility, flexibility management, product-customer segmentation

Motivation and problem statement
Today's supply chains compete in an increasingly complex, dynamic and uncertain business environment. Increased customer expectations, e.g. the demand for more product choice and features, for more responsive logistical services, and higher product availability, drive market dynamics. To alleviate the impact of unanticipated changes in supply or demand caused by these market dynamics, enterprises need to ask themselves how well their supply chain can adapt to changes.

Typical flexibility measures that target the compensation of uncertainties in supply chains are keeping safety stocks of finished goods and flexible capacities in production or distribution. The beneficial impact of these and other measures on the supply chain performance (e.g. delivery reliability) has already been shown in literature and is generally agreed upon long since (Godsell et al. 2011, Pfeiffer et al. 2012). Nonetheless, in their analyses of flexibility measures, researchers so far do not distinguish between different supply chain segments, although the application of measures is not equally beneficial for all product or customer groups. A more differentiated view on the supply chain in flexibility management is required, and a possible solution lies in the application of a segmentation strategy with the purpose of identifying distinct segments prior to the flexibility measure application.

This paper seeks to address this issue by introducing a segmentation procedure within flexibility management in order to allow for a product-customer-segment specific application of flexibility measures. We show that segment-tailored supply networks with homogeneous customer and product segments can improve flexibility management regarding benefits in terms of improved delivery reliability and profit. The approach is exemplarily evaluated in a practical scenario from the table-top product manufacturing industry using discrete event simulation.

The theoretical basics on supply chain flexibility and segmentation are introduced in the following section. Afterwards, the product-customer-segment specific flexibility management approach is explained, and the exemplary application as well as the evaluation results are presented. The paper concludes with comments on the managerial implications and limitations, a conclusion, and an outlook.

Theoretical basics

Supply chain flexibility

As a result of the extensive debate about the definition and characterization of flexibility, the research community has broadly agreed upon flexibility being a multi-dimensional construct (Sethi and Sethi 1990). We follow the definition from (Pfeiffer, Anwander and Hellingrath 2013): "Supply chain flexibility is the ability of a supply chain to change its structures, processes, resources, and steering mechanisms in the bounds of a given scope of action (given flexibility potentials)."

Current research has also suggested a large variety of flexibility types and dimensions, like lead time, product mix or routing flexibility, to name a few (More and Subash Babu 2008). We do not intend to fully investigate all potential flexibility types, but concentrate our analysis on volume flexibility, which is the ability to change the output level of products produced and delivered, and was already suggested by Beamon in 1999 (Beamon 1999). Volume flexibility is one of the most named flexibility types in the dominant literature and proven to have significant impact on delivery performance, especially in an uncertain supply chain environment with volatile demand (Jack and Raturi 2002).

Existing work on the conceptualization and measurement of supply chain flexibility has shown that flexibility range, time, and costs are the most important characteristics needed for a meaningful description of flexibility (Pfeiffer and Hellingrath 2011). The range corresponds to the question of what is changed and to which extent. It may denominate a capability, capacity, or behavior, or even a parameter of the aforementioned, which belongs to a supply chain's resources, structures, processes, or steering mechanisms. The extent of change is restricted within certain bounds, which define the scope of action. Regarding the time dimension, a distinction is to be made between the time needed for the setup of a flexibility measure and its effective use (cf. Aprile et al. 2005). While the flexibility potential is created in the long term, it is utilized in the medium or short term by the modification of supply, production, and distribution plans in order to cope with variability in demand volume and mix.

Similarly, the costs of a flexibility measure are distinguished into the costs for its setup and its utilization. For instance, quantity- or time-flexible contracts for the flexible sourcing of goods are measures where character and amount of costs due to their setup and utilization differ. While the setup may require high negotiation efforts, the utilization typically comes along with penalty payments for purchase quantities differing from forecasts or generally higher prices per item purchased. In general, the flexibility costs need to be practicable as well as reasonable when compared to the expected benefits.

Segmentation approaches

The theory of market segmentation was born out of the predominant idea that individual customers demonstrate heterogeneous demand and diversified requirements with regard to product and logistical characteristics (Smith 1956). Within the supply chain management context, segmentation approaches have revolved mainly around three fundamental segmentation approaches: the product-driven, customer-driven and the combined product-and customer-driven approach.

Product-driven segmentation on the one hand is the most prevalent and long-established form. It originated in Fisher's paper, in which the author suggests that different supply chain strategies are necessary for different product types (Fisher 1997). The output of product-driven segmentation is a set of product segments matched to appropriate supply chain strategies and solutions (cf. e.g. Christopher and Gattorna 2005, Lee 2002, Lovell et al. 2005, Vonderembse et al. 2006). On the other hand, the central idea of customer-driven segmentation is to conduct a detailed analysis of the customer base and to identify key segments. Researchers supporting this approach argue that product-oriented segmentation neglects customer-oriented criteria, such as logistics service expectations, revenue per customer and price sensitivity (cf. Walters 2006, Gattorna 2006). Lovell et al. e.g. propose a list of market-related variables that affect decisions on market segmentation, supply chain selection, and design (Lovell et al. 2005). Nevertheless, the proposed approaches have recently been criticized by researchers for being largely theoretical, too vague, and lacking empirical evidence and validation (Godsell et al. 2011).

Since product features and customer requirements both have a significant impact on supply chain decisions, the aforementioned segmentation approaches should be considered in combination. Several researchers have undertaken attempts to integrate both segmentation approaches and apply them in practice. For example, Godsell et al. propose a dual segmentation approach (Godsell et al. 2011). In a first step, the authors make use of important product-centric variables, namely the duration of the product life cycle, delivery lead times, volumes, variety and variability, to perform product segmentation. In the second step, the customers are then classified into two distinct groups with regard to their demand variability and order volume. Although the benefits of a combined segmentation approach are confirmed theoretically, only few practical cases can be found. Due to the aforementioned advantages, however, we expect the combined product-customer segmentation to be more beneficial. Consequently, we adopt this segmentation approach for the purpose of improving supply chain flexibility management, and describe the general concept in the following section.

Introducing segmentation procedures into flexibility management

A product-customer-segment specific flexibility management approach

In order to overcome the drawbacks of an undifferentiated supply chain flexibility management, we suggest the segment-specific application of flexibility measures following a four-step approach (cf. Figure 1). In the first step, the flexibility objectives are defined, including, for example, which target flexibilities (e.g. volume flexibility) to improve, which products or product groups to focus on, and which customer segments to address. Additionally, performance indicators which allow for controlling how well the objectives are achieved are selected. Defining the objectives and performance indicators depends on the supply chain situation under analysis and can only be performed case-specifically. However, we do not provide a method which supports determining the flexibility objectives and performance indicators, but refer to existing literature on flexibility management instead (Hocke 2004, Schorr 2008).

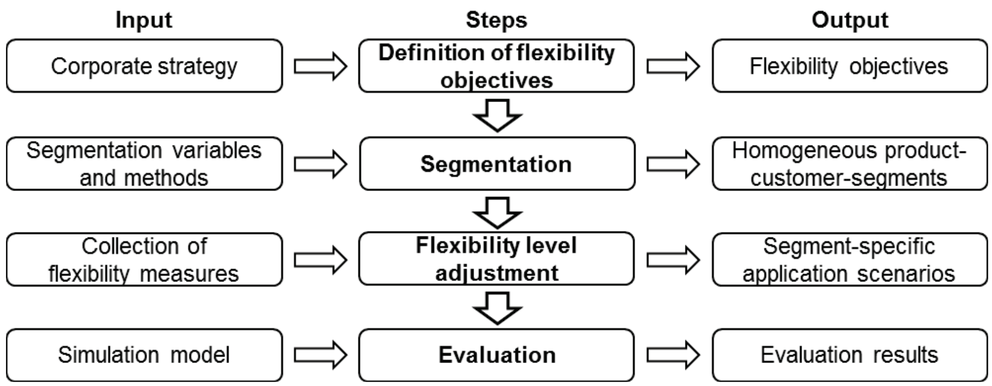

Figure 1 – Product-customer-segment specific flexibility management

In the second step, segmentation criteria are derived from the flexibility objectives, and homogeneous product-customer-segments are created. The segmentation criteria can, for example, be of demographic, geographic, or socio-economic nature, and the segments are determined by means of a two-step procedure which is described in the next paragraph. Afterwards, the flexibility measures which are applicable with regard to the identified product-customer-segments are selected. The set of available flexibility measures, however, is assumed to be known in advance. The selection is rule-based and builds on, for example, limits concerning the implementation lead time. Our approach concludes with an evaluation of the product-customer-segment specific flexibility measure application by means of discrete-event simulation.

Segmentation variables and methods

A segmentation variable is "a set of criteria or characteristics used to assign potential customers to homogeneous groups" (Wedel and Kamakura 2000). The decision maker first has to define the segmentation variables to be considered. Afterwards he has to position the chosen variables into a descending priority sequence. These prioritized variables are used to build up a segmentation criteria tree which lays the foundation of the segmentation approach. The values of the segmentation variables can be acquired by interviews or by analyzing a company's market and production data, e.g. sales rates or delivery times. In this approach, the segments are either built based on pre-defined boundaries, or with the help of cluster analysis. Pre-defined boundaries on the one hand are used if the decision maker wants to focus on special segments, e.g. first-class customers which are highly important to the firm. For generated boundaries on the other hand, we follow a two-step procedure. First, outliers which negatively affect the homogeneity of the resulting clusters are identified and treated separately. The outlier detection is performed based on the single-linkage method (Backhaus 2011). Thereafter, a hierarchical clustering method is used to identify the suitable number of clusters which is unknown in advance. We make use of the ward algorithm, because the following assumptions are fulfilled: outlier elimination in the data set, and existence of quantitative, metrically scaled variables (cf. Bergs 1980). We decide on the number of clusters to retain from the data as well as the corresponding boundaries by means of the so called elbow criterion (Backhaus 2011). This includes calculating all possible clusters ranging from a single, large cluster (having the highest heterogeneity measure) to many single-item clusters with a heterogeneity measure equal to zero. We plot the number of clusters on the x-axis against the distance at which clusters are combined on the y-axis. Afterwards, we search for the distinctive break (elbow) which determines the best amounts of clusters. As argued by Backhaus et al., the distinctive break between the first and the second cluster is neglected, because the highest heterogeneity gradient can always be found there (Backhaus 2011).

Selecting and evaluating flexibility measures

The subsequent selection of flexibility measures to apply to particular product-customer-segments is divided into two steps. A rule-based procedure first detects all flexibility measures that are not applicable in a segment or not beneficial regarding the flexibility objectives. Non-applicability in a segment on one hand is e.g. given if a measure concentrates on build-to-stock processes while build-to-order products were selected during the segmentation. On the other hand, a measure does not contribute to a flexibility objective if, for example, improving the target flexibility addressed by the measure is not a selected goal. Furthermore, the lead times and costs that come along with the flexibility measure application may not fit to the defined objectives as well. If a certain level of flexibility shall be reached in two weeks, measures that need more time to take effect can be disregarded. Based on these attributes (like setup lead times) and relations between target flexibilities and flexibility measures, the rule-based pre-selection is performed. The measures' attributes and relations need to be assessed in advance, but vary from case to case and can therefore not be generally defined. Relevant flexibility measures are general measures available in literature, but may also include best practices specific to the company applying this approach. In practice, however, the rule-based selection procedure can be implemented in information systems and may be automatically executed.

In the second step, the remaining flexibility measures need to be evaluated, and there are several aspects to take into account. First, the costs of flexibility have to be balanced with the expected benefits. Flexibility measures have to be selected for each segment, and the supply chain wide benefits as well as time and costs needed for the implementation have to be appraised. Unfortunately, their exact calculation is sometimes difficult (Pibernik 2003). For instance, initiatives to improve flexibility are most often triggered by uncertainties in the environment that expose businesses to risks. The benefits of flexibilities that reduce vague negative impacts of such risks are not easily measureable. As Jack and Raturi state, "the major problem is that flexibility inherently represents a capability that may not be exercised" (Jack and Raturi 2002).

There can also be interdependencies between flexibility measures in the same or across multiple segments. For instance, Krajewski et al. describe different scenarios where either manufacturing postponement or frequent production schedule updates are used as a means to improve volume and mix flexibility to cope with uncertainties in demand (Krajewski et al. 2005). In some settings, several flexibility measures can or should be used together to jointly improve flexibility. Gosling et al. (Gosling et al. 2010) describe a scenario in which different flexibility measures that seem to be opposed to each other at first glance are jointly used to enhance flexibility in procurement. On the contrary, some flexibility measures can hardly be applied simultaneously.

We suggest using discrete event simulation (DES) to cope with these issues. DES allows for the modeling of a supply chain's dynamic planning and operational processes as well as their complex interdependencies. It is well suited to perform a case-specific analysis in order to compare the (conjoint) application of flexibility measures to particular product-customer-segments while incorporating uncertainties. By running multiple experiments, the balancing of flexibility costs and benefits can be investigated and the behavior of cost and performance metrics with reference to the flexibility measures applied can be examined. Furthermore, the simulation model may be built on the data and performance metrics already available in a company's information systems, or could – in a more mature stage of development – even be integrated into them. In the following, we apply our approach in an example scenario from the table-top product manufacturing industry and demonstrate how it can improve flexibility management.

Exemplary application in the table-top product manufacturing industry

Practical context

The enterprise at focus is a producer of premium table-top products and packaging solutions for take-away food. The product portfolio ranges from candles, table coverings, plates & serving items to cups & glasses, cutlery, and party accessories. 88% of their production is made-to-stock (MTS) and 12% is made-to-order (MTO). The company has about 2,000 employees in 17 countries. Its brand is sold in over 40 markets and holds a number one position in Central and Northern Europe. The supply network comprises three echelons: a paper mill (supplier of raw materials), a converting plant, an international distribution center (IDC) which is located next to the plant, and regional distribution centers (RDCs) in different countries. A weekly planning run is carried out which determines a production plan, replenishment quantities, and shipment plans for all locations in the network. Raw materials requested from the paper mill are delivered to a raw material warehouse belonging to the plant. The regional distribution centers and the IDC serve the final customers. Some seasonal articles are sold for approximately three months only. Due to the seasonality, these products are subject to high variance in demand especially at the beginning and end of a product life cycle. Approximately 25% of the collection is replaced each year in response to that and to create new trends. Nonetheless, one of the most important business objectives is to serve customer orders at a delivery reliability of 90%. In a business that is characterized by demand fluctuations that are hard to predict, this target makes volume flexibility a major flexibility need.

Regarding the measurement, we restrict our analysis to the delivery reliability, operational costs, turnover and profit. By this we use metrics which are already available in most performance measurement systems and thus enable a quick implementation (both technically and organizationally) without any need for extra information to be gathered. Delivery reliability relates the amount of goods delivered in time to the total amount of goods ordered. It is calculated for each product, period, distribution center, product-customer-segment, and the whole supply chain. The segment-specific delivery reliability values are a valuable source of information while deciding on which flexibility measures to apply in which segment. The costs of supply chain operations are composed of costs for storage (interest and stocking), production, procurement, transportation, and flexibility.

Determining product-customer-segments and flexibility measures

During the analysis of segmentation variables and flexibility measures, we referred to possible criteria published in the literature, and we conducted semi-structured interviews with our industrial partner. The interview questions focused on revealing both critical targets and characteristics of the business environment which drive the companies' need for customer-product specific flexibility. Due to the business focus and competencies of our industrial partner, we emphasized on flexibility measures in distribution, in specific the leasing of additional warehouse capacity and running extra shifts which affect the maximal throughput of a distribution center. Regarding the segmentation criteria, we first differentiate between MTO and MTS products (cf. Figure 2). For our industrial partner, achieving a delivery reliability (DR) of at least of 90% is one of the most important business objectives. Consequently, our second criterion divides the MTS- and MTO-products into segments with DR□ 90% and with DR□ 90%. The next criterion in the segmentation tree is the demand fluctuation, which we describe by the standard deviation of the demand in relation to the average demand of the product during the planning horizon. Products with a high demand fluctuation (DF) receive a higher priority (DF>1.2), because stock-outs are likely and appropriate reactions by means of flexibility measures are expected to have the strongest impact in this segment. Finally, the annual revenue (AR) of a customer is used for separating differently valuable customers, anticipating that flexibility measures for more valuable segments pay off faster (AR>36,000). Figure 2 shows an excerpt of the resulting segments. For a more intuitive representation, we rounded the boundaries calculated by the ward algorithm, taking care not to influence the results.

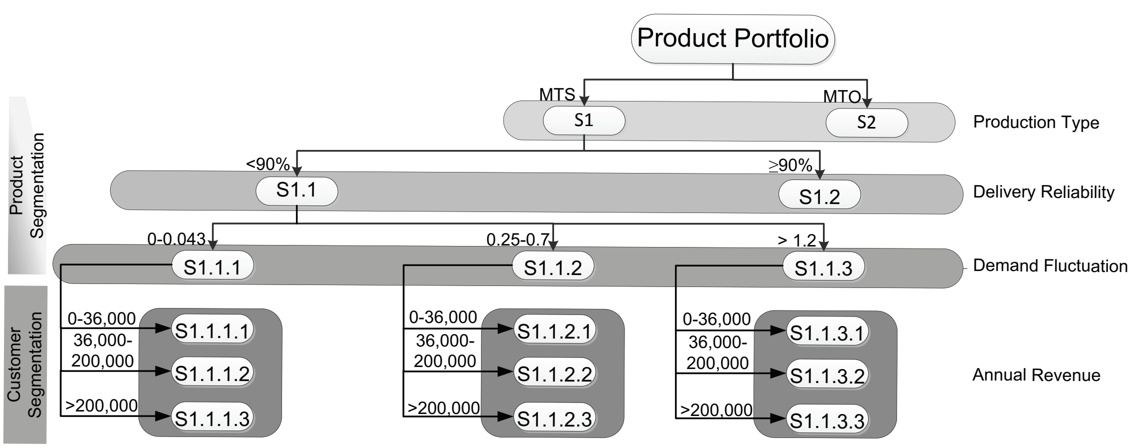

Figure 2 – Excerpt of the resulting product-customer segments and their boundaries

Evaluation results

We obtain inferences about the problem entity by conducting experiment runs of the simulation models using the software "AnyLogic" and following the simulation guidelines described in (Rabe and Hellingrath 2001). The simulation models are first run with default parameters as used by the industrial partner. Thus, KPIs concerning the actual operations can be measured with the help of historical industrial data and serve as the basis for comparisons. The model, i.e. the flowcharts, graphical models, and formal specifications, as well as the simulation results of this basic scenario are validated by representatives of the partner company.

Leasing additional warehouse capacity and running extra shifts to cope with throughput peaks (regarding incoming and outgoing shipments) are then made available to the master planning algorithm as potential flexibility measures. In weekly master planning runs, a cost optimization problem is solved which plans inventories, production, transportation and sourcing volumes, and the flexibility range to implement. Besides simulation runs which evaluate the segment-independent application of these flexibility measures, i.e. applying them indifferently to all products and customers, further simulation runs investigate the effects of implementing flexibility for a prioritized product-customer segment only.

Delivery reliability of products [not prio. / prioritized / total]	Demand scenario								
	Basic scenario			Demand increase			Regional dem. peak		
Without flexibility	60,52	51,29	55,32	62,74	49,85	55,61	62,48	57,69	59,80
Segment-independent flex.	86,37	77,96	81,73	87,36	78,77	82,65	84,96	68,43	75,86
Segment-specific flexibility	83,55	90,49	87,31	79,41	85,75	82,82	69,18	83,45	77,06

Table 1 – Comparison of delivery reliabilities (in %)

Table 1 shows three different demand scenarios of the table-top producer for chosen MTS products over four months. In the basic demand scenario we make use of the historical demand. In the second scenario we increase the overall demand by 10 percent. In the third demand scenario we increase the demand in only one country by 20 percent in order to show that it is not only possible to apply the segment-specific flexibility measures for the whole supply chain but even more focused on one dedicated location. For each demand scenario we calculate the delivery reliabilities according to a) applying no flexibility measures, b) segment-independent and c) segment-specific flexibility measures. Furthermore we differentiate between the total delivery reliability, and the delivery reliability for prioritized and not prioritized segments.

The results first show that implementing flexibility measures generally improves the delivery reliability, independent of using a segment-specific approach or not. The segment-specific application, however, allows for a more focused application. Taking the basic scenario as example, the improvement of delivery reliability for prioritized products is larger in the case of a segment-specific flexibility measure application, whereas non-segment products show a higher performance with a segment-independent application. Both approaches improve the delivery reliability, but the segment-specific application allows for a more focused application, i.e. it shifts the benefits gained from implementing flexibility towards the prioritized segments. Furthermore, it can be seen that non-segment products also profit from the segment-specific application, because the leasing of warehouse capacity and running extra shifts have location-wide effects. Thus, although the decision about their implementation is segment-dependent, non-segment products benefit from their effects as well, but to a lesser extent. Similar conclusions hold for the demand scenarios with a general increase in demand and a regional demand peak.

The beneficial impact of applying the flexibility measures only to prioritized product-customer segments becomes even clearer with a look at the costs and the profit related to the scenarios (cf. Figure 3). Across all scenarios, a segment-specific application of flexibility measures leads to a higher profit than the undifferentiated application. With unconstrained flexibility measures, i.e. with an unlimited flexibility potential, the segment-independent application would lead to the best results, because additional profit would be gained from increasing the sales volumes of all products with a positive contribution margin. In the scenario at focus, however, there are upper bounds to the leasable capacities and extra shifts. Therefore, targeting the flexibility measure application to the most beneficial customers and products leads to the better results in terms of profit.

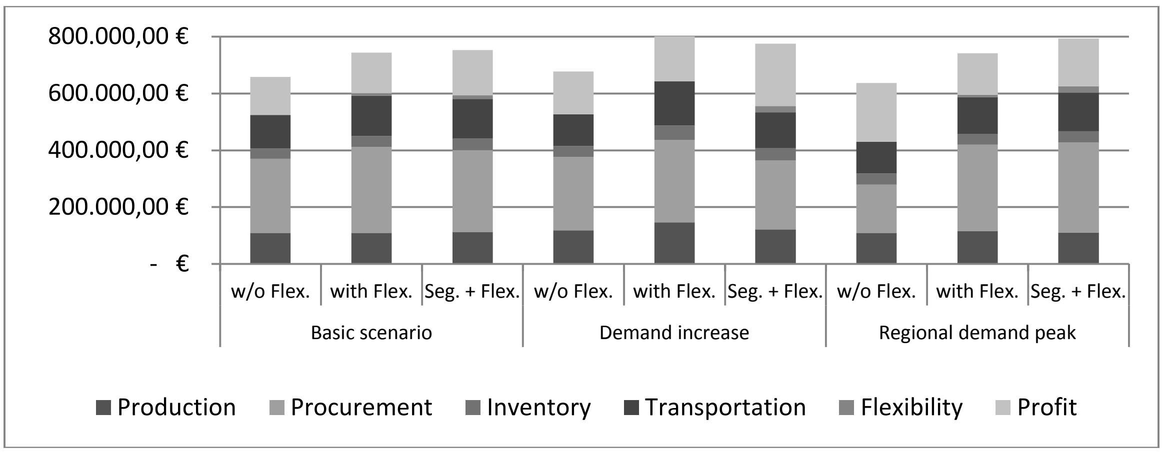

Figure 3 – Cost and profit comparison

Conclusion and outlook

The concept presented in this paper is a first step towards a segment-specific supply chain flexibility management. We have shown how flexibility management in a segment-tailored supply network can improve the supply chain performance in terms of delivery reliability and profit. Managers can build on this approach to align their flexibility management with their strategic objectives, especially if customer-oriented strategies are pursued.

By means of the exemplary analysis of leasing additional storage capacity and running extra shifts we seek to lay the groundwork for further analyses. However, the results are partially specific to our industrial partner and not exhaustive. Further investigations in other industrial scenarios, with alternative clustering algorithms and variables, or with different flexibility measures are required to support our findings.

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