# Flexibility measurement issues in supply chain management

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## Summary

Research Question: The essential problem being analyzed in the present paper is the search for methods to assess or rather measure supply chain flexibility. Due to a multi-dimensional characteristic supply chain flexibility is particularly difficult to analyze and to evaluate with adequate performance measurement instruments as they are often ineffective qualitative frameworks or quantitative metrics that are limited in scope, non-inclusive or not significant enough. The question therefore is whether there is a construct, a framework or any performance indicator that is capable of measuring supply chain flexibility adequately and that can be a benchmark; or is it necessary to develop an individual tool for a company because of its unique and special prerequisites to assess the flexibility of its supply chains?

Methods: Most researchers and practitioners that investigated flexibility more on an inter-firm perspective rather than relating it to supply chains. While having set the basis regarding the respective literature this paper follows a qualitative approach for the empirical analysis of the stated assumptions. Because of the exploratory character and the complexity of the subject expert interviews were conducted to get more in-depth insights and to derive conclusions concerning the correctness of the stated hypothesis.

Results: The theoretical analysis combined with the empirical investigation came to the result that measuring supply chain flexibility could not be possible by using only one performance instrument or one metric and accredits that no single KPI can give an accurate statement whether a supply chain is flexible. Only a combination of several different KPIs would we capable and it is concluded that due to unique supply chain objectives, individual structures, processes and products there cannot be a real benchmark model for every existing supply chain.

Structure of the Article: 1. Preface; 2. Literature Review; 3. Research Question & Hypothesis; 4. Empirical Approach; 5. Empirical Findings; 6. Conclusion; 7. About the authors; 8. References

## Preface

Today's business environment is becoming increasingly complex, unpredictable and uncertain for companies that operate in highly customer-driven markets. The grown pressure to create competitive advantages is combined with the impact by the requirements for shorter product innovation cycles and faster technological leaps. This situation results in the effect that a continuously growing number of entities faces an ambivalent challenge of trying to cut costs further while being more responsive and flexible towards changing customer requirements (Lummus et al., 2003; Singh & Acharya, 2013; Wadhwa et al., 2008).

A survey executed by McKinsey in 2011 revealed among other things that one of the biggest challenges nowadays that companies in cyclic industries have to cope with are uncertainty and volatility of market demands (Gyorey et al., 2011). Many firms face high order fluctuations which force them to adjust their production volumes quickly (Lambert & Cooper, 2000). The challenge of Supply Chain Management (SCM) in this context is to identify strategies that minimize cost while maximizing the flexibility which forces companies to be more creative regarding the alignment of their supply chain processes and to be able to react to various influence factors and disturbance variables (Fayezi et al., 2014; Pereira et al., 2009).

The global and dynamic markets demand better quality, more product variances and extended services including higher reliability and faster deliveries (Duclos et al., 2003). Each of those requirements can be a crucial differentiator that decide whether a company sustains on the market or not. Besides that, customized products with short lead times characterize the current situation in various industries. Together, all these factors provoke an uncertain environment where forecast errors are considera-

bly high. With customers wanting more diverging products, it becomes very difficult for the supply chain to transfer the customer needs into a product design and to predict the level of demand. To respond and react to uncertainties the increased strategic importance of flexibility in operations has been observed (Garavelli, 2003; Pujawan, 2004; Sethi & Sethi, 1990; Stevenson & Spring, 2007).

Flexibility is supposed to be a mechanism that enables firms to cope with far-reaching disturbance factors because it facilitates quick responses and is therefore a decisive criterion for customer orders. Also important to observe, is that improving flexibility in only one single element of a supply chain might be insufficient. An improvement of flexibility along the entire supply chain is necessary to achieve remarkable performance results (Winkler, 2008).

But measuring flexibility is a major issue for companies as it is a concept that can be assessed in different ways. Usually, for this purpose Key Performance Indicators (KPI) are supposed to be the instrument to monitor the factors that are needed to compare and evaluate how successful the organization is. Quantitative performance indicators might be used because the required data is available and because it can be set in relation to other performance metrics. The difficulty of developing adequate performance measures includes besides qualitative and quantitative aspects also issues of scope, e.g. whether the performance measure or measurement system should include one single organization or many. Besides, a performance measurement system that consists of a single performance indicator could be considered as inadequate since it is not inclusive and ignores the interactions of important supply chain elements (Beamon, 1999).

Based on this starting situation there is one central question that needs to be answered: Is there a construct, an existing framework or any performance indicator that is capable of measuring supply chain flexibility in an appropriate way?

For this reason, it is necessary to start with a clear process of defining and delimiting the concept from other ideas which are used very often simultaneously. Furthermore, there should be an idea how to assess flexibility in supply chains under certain circumstances and constraints that are enforced on a company. To solve the problem there needs to be an in-depth understanding of flexibility and its dimensions taking the different perspectives of a supply chain into account.

The used method contains a two-phase approach and is based on a comprehensive literature review followed by an adequate procedure for collecting the relevant data to support or disprove the hypothesis.

## Literature Review

Flexibility does not happen randomly. It's the result of strategic investments over many years. Due to its complex nature, it seems to be a difficult topic to analyze (Aprile et al., 2005). For a successful implementation of SC initiatives though, flexibility is among the most important factors.

### Delimitation of concepts

Within the literature, it is acknowledged that managing supply chains requires the administration of upstream and downstream relationships and processes with all the partners to bring value to the customer. Flexibility enables companies to do so but it needs to be distinguished and separated from the terms that are often used in the same context but correspond to a different supply chain focus. Researchers use terms like agility or robustness to describe similar phenomena but that pursue different objectives (Fayezi et al., 2014).

*Flexibility*

In science, flexibility has been profoundly discussed using various definitions and descriptions including a wide range of characteristics and dimensions. While in the 1980s and 90s the ideas were rather limited to flexibility issues within the company they were further developed beyond the borders of a single organization. Due to that, a variety of classification schemes and frameworks has been developed to provide a structure for the growing number of flexibility types and dimensions to clarify their distinctions (Seebacher & Winkler, 2013).

According to Sethi & Sethi (1990), flexibility is defined as the adaptability of a system to different environments. Gerwin (1993) came up with the definition that described flexibility as the ability to respond effectively to changing circumstances. He basically accredits the first perception but included and specified in his explanation the factor uncertainty of future events. Upton (1994) states that "flexibility reflects the ability of a system to change or react with little penalty of time, effort, cost or performance".

There are many studies that are mainly limited to the single-entity perspective and focused on factors like the influence of flexibility on the company's internal operations (Vickery et al., 1999). On the contrary, there have not been that many elaborations which investigate flexibility on an inter-firm perspective. This embraces not only the flexibility of production systems but the flexibility of different functions and processes (Aprile et al., 2005).

In the recent years, research on flexibility has appeared significantly, especially the literature concerning SCF. Kumar, Fantazy and Boyle (2006) observe flexibility from the viewpoint of global supply chains. This progress towards a multi-functional application of flexibility is going to be investigated in a later stage. But considering

that, there are some basic principles of flexibility can be applied to supply chains:

Supply Chain Flexibility is multi-dimensional: being flexible in one dimension does not necessarily mean that the analyzed unit will be flexible in another (Stevenson & Spring, 2007). Besides, some elements or dimensions of flexibility are more important in certain environments than in others with uncertainty as the main driver and starting point (Fayezi et al., 2014). Flexibility is a crucial capability that enables an entity to adjust processes, capacities and operations while helping to overcome the mismatches and conflicts among the different involved parties in a supply chain (Lummus et al., 2003).

These definitions imply that it deals with an ability of a company to react to unexpected events effectively which prevents a loss in time, cost and efficiency and consequently would lead to significant performance improvements. Flexibility can be observed as a response to external uncertainty and perceived as an attribute or capability of a system to cope with many environmental uncertainties and changes.

*Agility*

The concept of an agile company came up as the result of a cross-industry workshop in the 1990s, the so called "Agility Forum", and was initially defined as "the ability of an organization to thrive in a continuously changing, unpredictable business environment" (Kumar et. al., 2008). Since then, many definitions have been put forward about this topic. For an entity to be agile means embracing a faster response to the business challenges of rapidly changing and continuously fragmenting global markets (Goldman et al., 1995).

Agility is a very broad concept that can also be defined as the firm's ability to quickly adjust tactics and operations within its supply chain to respond or adapt to changes, opportunities, or threats in its environment (Dittmann et al., 2013). Agility deals with the ability that a company needs to positively react and quickly take advantage of these changes. Behind the perception of an agile supply chain is the idea of fast adaptation, delivering products and services to fulfill customer needs rapidly and cost efficiently. Reaction and the flexibility of operations is the main linkage between the two concepts (Prater et al., 2001).

The observed difference to the previous concept is that flexibility it is a subset of agility. According to Prater et al. (2001) supply chain agility consists of two elements: flexibility and speed. As flexibility is required to be agile the factor speed is the important difference between the two concepts. In an environment where time to market is an essential aspect agility means being one step ahead to use flexibility and other components like speed to be the first that brings value to the customer (Prater et al., 2001).

Taking these descriptions and definitions into account it can be interpreted that agility is the successful use of resources to enhance the own competitive edges and to provide customer-driven products or services and react quickly in fast-developing market environments. It further implies that a company that is perceived as agile is one with a broad vision and the look for mega trends and market segments in which new business can be conducted. An agile organization might also be able to perceive or forecast changes and create capabilities to deal with them in a proper way but especially react faster than the competition.

*Robustness and Resilience*

An organization or supply chain that is following the previous stated approach is usually referred to the concept of reactive strategies and implies that it adjusts to changes after a certain event in time. This corresponds primarily to being flexible or agile and being able to adapt procedures and operations. In contrast to reactive strategies, robustness is a proactive strategy that can be defined as the ability of an entity or supply chain to resist change without modifying its initial orientation (Durach et al., 2015). Proactive means that e.g. a supply chain implements measures to cope with turbulence without a specific adaptation. Entities that follow such a strategy are usually referred to as robust when it corresponds to being stable. It describes the competence to maintain performance during times of change through proactively implemented measures (Christopher & Peck, 2004).

The concept of resilience, another term used in this context, means to balance both reactive and proactive strategies. Wieland and Wallenburg (2013) constitute that resilience is the capability of a supply chain to overcome change also stating that it consists of agility, resulting from flexibility and speed, and robustness, coming from anticipation and readiness. Resilience can also be seen as the adaptive capability of the supply chain to prepare for unplanned incidents, respond to errors and recover from them (Durach et al., 2015; Wieland & Wallenburg, 2013).

After analyzing the relevant ideas and terms in the context of flexibility there is a basic conclusion to be made. Flexibility is the underlying construct of all the concepts that were developed as advancements with far reaching results and possibly game-changing effects for SCM. A central conclusion that can be made is that uncertainty is the central trigger that makes flexibility and other related concepts necessary.

**Uncertainty as driver for flexibility**

Uncertainty as a circumstance and premise of flexibility is widely accepted within the literature. Different types of uncertainty require a certain and different form of flexibility which makes it obvious that there is a relation between uncertainty and the function of flexibility in SCM (Fayezi et al., 2014). Uncertainty refers to a situation where an unpredictable event impacts the performance of an entity and is often connected to the lack of accurate

information available for a proactive decision making (Vilko et al., 2014). In the attempt to prepare for uncertainty, estimates for risk are used to characterize different environmental influences.

Research into the topic of risk management has been very influential in developing a better understanding of the role that uncertainty plays in the supply chain, and how it can be managed but also mitigated (Fayezi et al., 2014). The literature mentions that uncertainty is a complex and inter-related phenomenon that can occur at any point along the supply chain (Davis, 1993). It is concluded that it is essential for managers to have a comprehensive understanding of the cause and effects that exist between internal and external as well as upstream and downstream relationships in the supply chain. Following this, the enhancement of flexibility within activities, subsystems, processes and functions of the supply chain is very likely to increase the ability of an organization significantly to respond to uncertainties (Jüttner, Peck, & Christopher, 2003).

Decoding uncertainty in the supply chain requires a profound view on all supply chain functions. Uncertainty is tightly connected to supply chain flexibility as a part of modern risk management. It can be categorized into different levels of influence, such as market or demand changes, progress of technology developments, political and economic instability, laws and regulations, currency fluctuations and macroeconomic situation (Vilko et al., 2014). Looking at the different supply chain functions a cluster can be created to describe different types of uncertainty arising from upstream and downstream relationships.

Supply:

Supply-related drivers concerning the use of material and the choice of supplier provide a base from which to analyze upstream supply chain uncertainties. It is supplier flexibility combined with flexibility of the procurement process that enables an entity to manage the various factors of uncertainty that it might encounter. Such factors are, for example, insufficient capacities, wrong scheduling, material unavailability, production shortfalls or financial problems that all have the potential to affect the supply performance negatively (Fayezi et al., 2014).

Process:

Uncertainty and risk management in manufacturing systems includes a diverse range of taxonomies. Process uncertainties may occur both across and within the operational and functional parts of the organization. Failure within the value creation process is a major issue for manufacturing companies but there are other factors like the lack of skilled workers, employee fluctuation, machine breakdowns as well as other technical shortfalls which all are sources of risk and uncertainty within service and manufacturing operations (Sethi & Sethi, 1990; Upton, 1994). They are crucial factors to be prevented as they can cause serious problems and a tremendous increase of cost in case of their appearance. A flexible workforce, for example, which is able to perform operations in different process steps has the potential to contribute to the stability of organizational performance (Fayezi et al., 2014).

Demand:

Downstream-oriented supply chain flexibilities are directly linked to uncertainties with demand. Companies face a range of uncertainties caused by, for example, forecasting errors, demand volatility, lack of market transparency as well as non-visibility of competitive information and sub-optimal inventory strategies (Soon & Udin, 2011; Wadhwa et al., 2008). The importance of coping with demand uncertainties requires the organization's ability to respond to individual customer requirements. Quick reactions have the potential to increase the customer satisfaction and encourage the development of long-term relationships (Jüttner et al., 2003). In this context, delivery flexibility is fundamental to a company's capability to provide products and services under changing market conditions. Furthermore, the partners involved in downstream activities need to be aligned to reduce the impact of the external factors (Pujawan, 2004; Stevenson & Spring, 2007). Getting along with all types of risk and uncertainty implies to have a number of mitigation strategies to avoid being negatively influenced.

There are different attempts to provide strategies that reduce supply chain risks while at the same time increase the adaptability of entities. The identified measures and suggestions are often referring to the design of supply chains but also focusing on the number of SC partners. Some researches state that a reduction of involved parties would enhance the performance, others suggest that enlarging partnerships, for example, by using multiple sources, or intensifying them by creating collaborative relationships across the supply chain reduces risk. "Soft factors" such as trust and commitment but also risk sharing, JIT or JIS delivery models and inter-organizational information systems are also supposed to increase the flexibility (Acur et al., 2009). The enablers for flexibility are: multi-sourcing, localized sourcing, supplier selection, development and certification, joint product development with suppliers, long-term customer relationships, third party logistics providers with strategic inclusion, alternative modes and routes of transportation, external and internal integration (Fayezi et al., 2014; Kumar et al., 2008; Pujawan, 2004)

Researchers have discussed flexibility as one central ability to respond to uncertainties in the business environment (Prater et al., 2001; Upton, 1994). Despite the development of detailed concepts and tools, there is still no holistic framework that allows the mapping of uncertainty types with flexibility dimensions and other mitigation strategies throughout the whole supply chain (Fayezi et al., 2014).

From the point of view of a single organization, Jüttner et al. (2003) distinguish five generic strategies that companies undertake to mitigate risk, four of which can be adapted to supply chain contexts: avoidance, control, cooperation and flexibility:

| | |
|---|---|
| **Avoidance** | • Dropping specific products, markets, suppliers, service providers or customer organizations<br>• Skipping risky geographical markets and politically instable regions |
| **Control** | • Vertical integration<br>• Increased stockpiling and the use of buffer inventory<br>• Maintaining excess capacity in productions, storage, handling and/or transport<br>• Imposing contractual obligations on suppliers |
| **Cooperation** | • Joint efforts to improve supply chain visibility and understanding<br>• Joint efforts to share risk-related information<br>• Joint efforts to prepare supply chain continuity plans |
| **Flexibility** | • Postponement<br>• Multiple and localized sourcing<br>• Use of different distribution channels |

Figure 1:
Mitigation strategies against uncertainty (Jüttner et al., 2003)

The literature review leads to the assumption that risk mitigating strategies in supply chains should be investigated in combination with its direct drivers. A final, maybe decisive decision is between mitigating risk and delivering value. This is the trade-off between the extra costs related to most of the mitigation strategies and total cost reduction as a main principle of contemporary supply chain management. Considering, that flexibility is one of the strategies to reduce the negative impact caused by uncertainties, this elaboration helps to understand that there is no universal remedy to prevent unplanned events in dynamic supply chain management. Flexibility can be considered as one main pillar to mitigate the risk of suffering from heavy influence factors which may cause serious supply chain disruptions. Nevertheless, the concept has to be further investigated to learn how the different components of flexibility interdepend and how they can be assessed.

**Supply chain flexibility types and dimensions**

Through the literature valuable insights on supply chain flexibility and its characteristics over the past decades have been gained which led to a discussion whether flexibility might be more relevant for different supply chain perspectives and supply chain objectives. Singh and Acharya (2013) analyzed different concepts and ideas of flexibility and argued that each company systematically balances different flexibility types and dimensions under differing conditions. The authors may have identified different dimensions of SCF. However, these characteristics should be related to the respective supply chain functions. This usually includes purchasing material, manufacturing products and shipping the finished goods to the customer (Pujawan, 2004). Nevertheless, according to Lummus et al. (2003) most of the literature on flexibility failed to emphasize the cross-functional, cross-business nature of supply chain management.

Flexibility in supply chain management is the derivative of flexibility from a single entity point of view with various components and sub-components (Singh & Acharya, 2013). Before the transfer to supply chain management there have been different researchers who mainly focused on the internal aspect of flexibility. Initially, the concept of flexibility was limited to manufacturing flexibility and was later extended to the entire supply chain. Sethi & Sethi (1990) defined manufacturing flexibility as the ability of an entity to reconfigure resources to efficiently produce different products of acceptable quality. Gerwin (1993) described it as the ability of the manufacturing system to adapt its capabilities to create quality products in a time and cost effective manner in response to changing inputs. Various research articles on manufacturing flexibility distinguish types of flexibility such as machine, labor, material handling, operation, volume, mix and modification (Sethi & Sethi, 1990; Upton, 1994). Some of these types though are directly linked to process steps and operations before and after the manufacturing process. At that point of time though, it was not evident that flexibility within the entire supply chain is the result of the components at each node of the supply chain and its interdependencies.

Vickery et al. (1999) were one of the first groups of researchers that defined five supply chain flexibilities based on the existing literature. The authors stated that supply chain flexibility should be investigated from an integrative, customer-oriented perspective. Flexibility was seen as directly impacting a customer and the responsibility of two or more functions, whether internal or external to the firm, are included. The five defined flexibilities include: Product flexibility, the ability to customize product to meet specific customer demand. Volume flexibility, the ability to adjust capacity to meet changes in customer quantities. New product flexibility, the ability to launch new or revised products. Distribution flexibility, the ability to provide widespread access to products and finally responsiveness flexibility, the ability to respond to target market needs (Vickery et al., 1999)

These dimensions of flexibility though cannot be considered as fully seeing the inter-firm component of flexibility. Supply chain flexibility requires both internal flexibility and flexibility between supply chain partners. They identified the cross-functional aspect of flexibility in SCM but stick to the single entity. Their descriptions of flexibility are endeavored in terms of flexibility types that are required to respond to customer demand. Not apparent in this context is what is necessary to make a supply chain flexible in meeting those customer requirements. Besides, the consideration of inbound flexibilities is not given but plays a vital role in the evaluation of flexibility among the whole supply chain.

Lummus et al. (2003) recognized that flexibility of the entire supply chain is a result of the characteristics of the operations systems, the logistics processes, and the supply network at every point in the supply chain. They suppose that some of the operational characteristics result in a flexible supply chain but are heavily influenced by the organizational design and information systems of each supply chain partner. They further state that when customer needs are fully satisfied, even when the needs change over time, the supply chain has achieved market flexibility. By being flexible, the supply chain can meet specific customer requirements and enhance a long-term commitment of customers (Lummus et al., 2003).

Sánchez and Pérez (2005) also discussed characteristics of flexibility and created a conceptual model that suggests the relationship between supply chain flexibility and firm performance. According to them, flexibility abilities are enhanced in surroundings with higher environmental uncertainty, technological complexity and lower cooperation between the involved parties in the supply chain. They measured the importance of several dimensions of flexibility on a scale to observe their effects on the performance. These dimensions are delivery flexibility, routing flexibility, response to market flexibility, volume flexibility, product flexibility, access flexibility, transshipment flexibility, launch flexibility, postponement flexibility and sourcing flexibility.

Stevenson and Spring (2007) reviewed some researches and referred also to the work of Sánchez and Pérez on supply chain flexibility. They discussed that there is a hierarchy of flexibility and its dimensions categorizing the types of flexibility into tactical flexibilities, operational flexibilities, supply chain flexibilities and strategic flexibilities.

The analysis of the most common and acknowledged researches revealed that supply chain flexibility contains different perspectives and further can be divided into hierarchy levels like e.g. the operational and the strategic level. Based on the investigated literature and studies a consolidation and summary of flexibility dimensions can be developed to explain in detail the characteristics and forms of flexibility in supply chains:

1. Sourcing Flexibility: It is the ability of an organization to have more than one single supplier for the same or similar kind of input material. In case one source is not able to provide the required quantities or if the received material doesn't fulfill the default quality companies are flexible enough to have substitutes that can deliver pursuant to the requirements (Kumar et al., 2006; Sánchez & Pérez, 2005).
2. Supply Flexibility: Supply flexibility refers to the flexibility within the ordering process. To consider a supplier as "flexible", he should offer different delivery models regarding the point of time, quantity and the location of desired raw material or components (Pujawan, 2004; Singh & Acharya, 2013).
3. Transshipment Flexibility: It is the ability of organization to transfer and arrange the products among different warehouses or other stocking locations through replenishment strategies. Transshipments are monitored movements of goods between storage locations and provide an effective mechanism for correcting discrepancies between the observed raw material demand and their available inventories (Sánchez & Pérez, 2005).
4. Machine Flexibility: It's the ability of a machine to perform various tasks. This is referred to the range of operations that a piece of equipment can perform without incurring a huge setup. It deals with a type of flexibility to provide organizations with the ability to change the layout of a production system rapidly (Lummus et al., 2003; Stevenson & Spring, 2007).
5. Product Flexibility: Product flexibility can be described as the adaptability to any future change in product design, including new products and variances of existing products. It allows a quicker response to customization requests and simplifies the

handling of non-standard orders. Postponement as an example for a late product variation enables firms to trigger the start of product differentiation only when a clear demand signal is available to keep the product until that point of time in a standardized form (Sánchez & Pérez, 2005; Stevenson & Spring, 2007; Vickery et al., 1999).

6. Volume flexibility: It's the ability to produce above or below the planned lot sizes or capacities for a certain product. Volume flexibility enables the firm to produce in response to fluctuating demand levels (Sánchez & Pérez, 2005; Vickery et al., 1999)

7. Labor Flexibility: Labor flexibility is the ability to assign tasks to a varying number of operators. It is referred to the flexibility of employees to work in different areas of manufacturing but also to work in different shift models. Labor flexibility allows multitasking and the execution of various tasks. (Lummus et al., 2003).

8. Delivery Flexibility: It's the ability of an organization to adapt the frequency of deliveries according to customer wishes and enables to adjust lead times and quantities correspondingly. This measure is linked to volume flexibility as one prerequisite for delivery flexibility (Beamon, 1999; Kumar et al., 2006).

9. Distribution Flexibility: Distribution flexibility means to be able to change the mode of transportation as required. This means, a product that can be delivered through multiple ways needs a higher level of outbound logistics flexibility than a product that is transported via a single delivery mode (Lambert & Cooper, 2000; Stevenson & Spring, 2007).

10. Access Flexibility: Access flexibility is linked to the ability to have several options of distribution and sales channels focusing on requirements of direct and indirect customers. It enables to provide a widespread coverage which is facilitated by close coordination of supply chain downstream activities. Partners like retailers or wholesalers are directly involved in this process (Sánchez & Pérez, 2005).

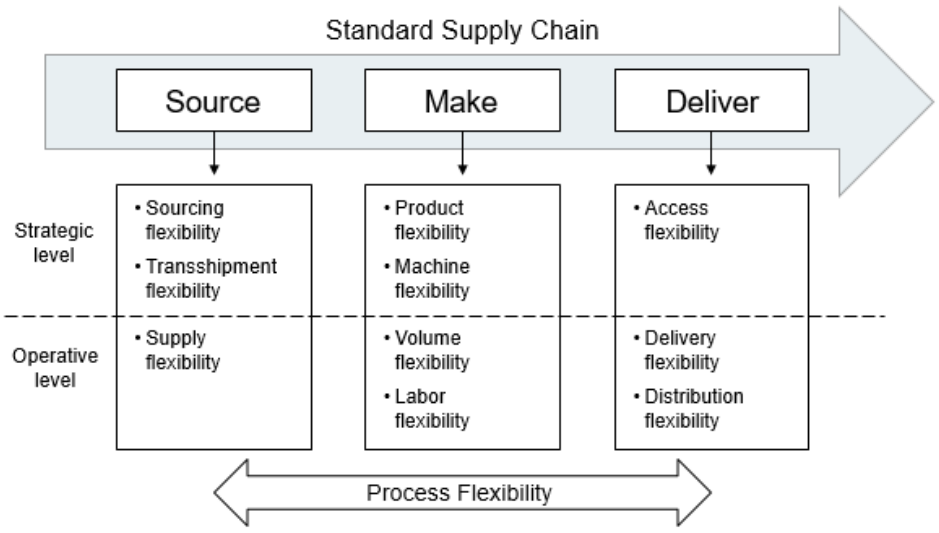


Figure 2:
Flexibility types and dimensions in a supply chain (own picture)

**Measurement of Flexibility**

After identifying the numerous dimensions and types of flexibility in supply chains the challenge for an organization is the evaluation and assessment of performance based on the flexibility characteristics within the supply chain functions. Therefore, the selection of measurement instruments is a critical step in the design and testing of a system. Generally, the larger and more complex the system, the more challenging it becomes to measure it effectively (Beamon, 1999). Although there has been an increasing number of researches on supply chain performance management, there is little available about supply chain flexibility measure selection. Many of the existing studies use ineffective performance metrics that are limited in scope, they are non-inclusive or they miss relevant input data (Wadhwa et al., 2008). Obviously, the use of

simple KPIs is tempting, as plain measures can be implemented more easily. However, by limiting the scope of a measurement system, important performance characteristics might be ignored. To improve the effectiveness of SCF measures, performance metrics have to be selected which will allow an accurate evaluation (Beamon, 1999).

Besides, assessments of individual flexibility types are sometimes incorporated in broader performance measurement frameworks. Flexibility measures are considerably different from regular resource and output measures (Beamon, 1999). Measuring the grade of flexibility is difficult to obtain thus existing measurement instruments are often criticized because of the following aspects: Measures can be subjective and situational as they lack generality (Beamon, 1999; Gerwin, 1993). Beyond, flexibility is a measure of potential (Beamon, 1999). And flexibility is multi-dimensional: being flexible in one dimension doesn't mean that the analyzed unit will be flexible in another. Therefore, two supply chains could be equally flexible but in very different ways (Stevenson & Spring, 2007).

The literature that tries to measure supply chain flexibility remains in its infancy (Stevenson & Spring, 2007). What is available can be divided into work that assesses "hard" factors (Beamon, 1999; Giachetti et al., 2003) and literature which mentions "soft" factors (Gupta & Nehra, 2002; Pujawan, 2004). Soft factors, such as flexibility in relationships, are usually assessed by using rating scales or expert opinions. Despite providing useful contributions, the works can also be criticized for including only a limited number of components of flexible supply chains, giving insufficient details on how they can be applied in practice and, like assessments of manufacturing flexibility, for being very situational (Stevenson & Spring, 2007). Other papers which focus on the performance measurement of supply chains (e.g. Lambert et al., 1998) give flexibility an insufficient attention. Hard factors can be measured directly, for example, the total coverage time, delivery performance or the total cost of ownership. The supply chain operations reference (SCOR) model, a management support tool developed by the Supply Chain Council (2015), describes business and supply chain processes, enables companies to analyze them, assesses and improves those processes and provides help for the decision making.

When analyzing the performance of a system, qualitative evaluations such as "good", "fair", "adequate", "poor" or "bad" are vague and difficult to use in any meaningful way to compare two systems (Beamon, 1999). The use of quantitative performance measures seems to be more attractive, easier to compare than qualitative ones and generally more significant in their information about a system. But it has to be ensured that by utilizing a quantitative one, this measure adequately describes the whole performance. Beamon (1999) identified and evaluated individual supply chain performance measures corresponding to three categories: resources, output and flexibility. The mentioned resource measures are mainly related to costs and return rates, the output measures are directed to delivery performance, inventory and backlog metrics while the flexibility measures correspond to different types of flexibility. Despite the detailed description, she concluded that there were significant weaknesses in each of the developed measures based on criteria like inclusiveness, universality and practicability. The most noticeable weakness of these performance metrics was their missing inclusiveness. For a measure to be inclusive, it must measure all suitable aspects of the supply chain. Considering an example where a company decides to increase flexibility in production, the supply chain might be operating with high manufacturing flexibility, it still may simultaneously demonstrate poor customer response performance, or it might miss the flexibility to meet supplier outfalls (Beamon, 1999).

One of the most valuable contributions with regards to quantitative performance metrics is the SCOR model. It describes and determines fundamental processes of the supply chain and it contains several key metrics for measuring supply chain performance (Varma et al., 2006). It was introduced by the Supply Chain Council (SCC), an independent, non-profit corporation focused on applying and advancing the state-of-the-art supply-chain management systems and practices (Li et al., 2011). The SCC was founded in 1997 by 69 supply chain practitioners from different industries that formed a cross-industry-forum to discuss developments related to supply chain management.

The SCOR-model contains five components: Plan, Source, Make, Deliver and Return. Each of them considers important intra-company functions but also those which happen between two or more companies. The framework can be considered as a strategic tool for describing, implementing, controlling, and measuring complex supply chain processes to achieve a high level of performance. The SCOR-model specifies performance metrics that are divided into two categories: customer-facing metrics that include responsiveness, reliability, and flexibility, and the internal-facing metrics that focus on cost and assets (Poluha, 2007).

The Supply Chain Council has maintained and refined the SCOR model to measure the cross-functional and inter-company supply chain processes. Its main metrics measure five supply chain performance attributes: Supply Chain Reliability, Supply Chain Responsiveness, Supply Chain Agility, Supply Chain Costs and Supply Chain Assets. Supply Chain Responsiveness e.g. measures the time to fulfill customer demand. The used KPI is Order Fulfillment Cycle Time, which looks at the number of days to fulfill an order. Here it deals with a regular order that is expected and planned. In contrary, the Supply Chain Agility performance indicators measure the ability of a supply chain to respond quickly to changes in the market and to gain or maintain competitive advantages (Ainapur et al., 2011).

<u>Upside Supply Chain Flexibility:</u>

In the present context "upside" and "downside" refers to the direction of demand change. A demand increase means upside, a decrease means downside. Upside SCF is defined as the number of days required to achieve an unplanned sustainable 20% increase in quantities delivered (Bolstorff & Rosenbaum, 2007, p.144 ff.). A company e.g. has been selling approx. 10,000 pieces of a particular product in a certain month over the past couple of years. Now, in the particular month this year, the demand has increased by 20% to 12,000 pieces. The situation requires to have either more stock, capacities or employees to produce the 2,000 pieces of extra demand. If there is enough vacant capacity the company is able to produce the 2,000 within the same period. But, most companies operate very lean and try to come close to a 100% utilization. If this takes for example five extra days to fulfill the 20% monthly demand increase then this would be the upside supply chain flexibility.

Upside Supply Chain Adaptability:

Upside Supply Chain Adaptability is defined as the percentage of increased production quantity that a company can achieve and sustain in 30 days (Bolstorff & Rosenbaum, 2007, p.144 ff.). Taking the same example as before, a company used to produce 10,000 pieces in a month. There is a call for bids from a potentially big new customer which would buy a huge amount of units and the company has to ask itself how much it can produce extra in 30 days. The company had to produce 10,000 pieces but now, in order to acquire this new customer, it plans to utilize the whole capacity and adds shifts, hires workers, outsources to third party for certain tasks and finally is able to produce 5,000 additional pieces than before within the 30 days. This company therefore can produce 50% extra in 30 days' time which is its upside supply chain adaptability.

Downside Supply Chain Adaptability:

Downside Supply Chain Adaptability is defined as the percentage of quantities that are sustainably reduced compared to the standard quantity with 30 days' reaction time not having extra inventory or causing cost penalties (Bolstorff & Rosenbaum, 2007, p.144 ff.). Again, an organization used to produce and sell 10,000 pieces a month. Suddenly, there is a huge drop in sales and the demand is much lower than before. When this company now sustainably produces 8,000 pieces per month without incurring inventory and cost penalties from e.g. suppliers it is able to reduce operational costs respectively so their cost per piece is still the same. It then establishes a 2,000 pieces' reduction in order quantities within 30 days and is still able to sustain. The company`s downside supply chain adaptability is 20%.

The investigated KPIs from the SCOR-model provide a solid basis and a good support to assess and measure changes in demand as one aspect of uncertainty and can therefore be taken as a fair method concerning the evaluation of one flexibility element in supply chains. However, taking all the aspects of the theoretical elaboration into account, it is still just one component of supply chain flexibility. Hence, taking one of these KPIs as central indicator for the overall assessment of flexibility in a supply chain, not considering for example supplier uncertainties or product flexibility aspects, can actually be seen as non-inclusive and insufficient. As mentioned earlier, a SCM system that consists of a single performance measure could generally be seen as inadequate since it ignores the interdependencies among important supply chain characteristics. The diagnosis of inaccuracy in the assessment of all flexibility aspects in a supply chain using quantitative and qualitative methods leads to the assumption that due to the complexity of this topic there is generally no tool or measurement instrument that is able to give an accurate information about the degree of flexibility. Combining the findings from all the previous sections makes it obvious that the concept of flexibility needs individual approaches for its assessment or measurement.

## Research Question & Hypothesis

Based on the starting situation, there was placed one central research question that has to be answered: Is there a construct, a framework or a performance indicator that is able to measure or assess flexibility adequately and that is capable of being a benchmark for other companies; or is it necessary to develop an individual tool for a single organization due to its unique and special characteristics to evaluate the flexibility of its supply chains?

In spite of a detailed analysis of definitions and a delimitation of many theoretical concepts with regards to flexibility, it seems that a big number of researchers has totally distinct perceptions when it comes to the topic of supply chain flexibility. What can be seen though as common understanding is that supply chain flexibility is a multi-dimensional concept with many characteristics, dimensions, enablers and drivers.

**Hypothesis:** There is no single performance indicator or any metric on the quantitative side which is able to measure Supply Chain Flexibility adequately but there is also no existing framework that is capable of measuring flexibility on the qualitative side. Merely a combination of several KPIs can bring an additional value for an accurate evaluation of supply chain flexibility.

## Empirical Approach

Having analyzed existing research and having identified some of the gaps, this paper pays special attention to the different characteristics and dimensions of flexibility and the instruments for its evaluation. Such aspects like complexity and difficulty of understanding the topic in detail

had therefore much influence on the methodology, the research strategy and the choice of an adequate data collection method.

*Data Collection Method*

Several factors influence the degree of the structure or the type of instrumentation used in a qualitative research study. The purpose of the study was the most important decision driver as it was more exploratory and attempted to discover or refine some theories and concepts (Devers & Frankel, 2000).

The central source of data collection used in the present research was primary data from expert interviews. For the underlining purpose of this study, collecting in first place information about tools to measure flexibility in supply chains, semi-structured face-to-face interviews with supply chain experts were developed. To reduce the complexity, the number of interviews was reduced to eight. It was essential to choose the right experts that represent the main functions in the supply chain and that have specific knowledge about their area in the supply chain as well as about the right usage of performance measurement instruments. In the present case, experts were taken from areas that represent purchasing, sales, production planning, project management, logistics and controlling. These interviews helped to provide insightful data on the specific research targets. For the interviews, a conversation guideline was used which consisted of semi-structured questions, allowing for comparability of answers and improving the reliability of the study.

Taking the theoretical analysis of this thesis into account, it was necessary to find a common base for the following questions in the interview. As flexibility has various characteristics and varying interpretations, there was the assumption that all expert could perceive flexibility differently from different positions and responsibilities. For that reason, the interviews are divided into four main blocks focusing on different contents. The first part serves as an introduction of both interview partners to get to know each other. The second one deals with the general understanding of flexibility and the personal association with the concept from the expert's perspective with questions leading to a general definition and importance of flexibility.

The third group of questions directly focuses on flexibility in supply chains as well as the types and dimensions. The experts were asked what SCF types they would know and what requirements they have towards it. One important question concerning the significance of the hypothesis was the question when a supply chain is flexible. The aim of asking this question was to find out whether there might be a clear conformity in the given answers or whether the perception of being flexible in a supply chain strongly varies. Also, the question which requirements the experts would have towards flexibility in supply chains was asked to confirm or refuse the assumption that every function in the supply chain has different perceptions. A purchaser would see flexibility most likely from an inbound perspective while a production planner probably would focus on flexibility in manufacturing processes which can be transferred to others that presumably would have the same perceptions.

The fourth group of questions was the most important one concerning the research question and the stated hypothesis that no single KPI would be able to measure SFC in a completely satisfying and including manner. It mainly deals with tools for measuring flexibility and the significance of KPIs regarding their capability for giving an information whether a supply chain is flexible or not. Starting with an introductory question if the experts already had contact with flexibility measurement instruments was addressed to find out if they already know existing instruments. Afterwards, the experts were shown an enumeration of several generic and logistic KPIs and KPIs from the SCOR-model. During the interviews the KPIs were described in detail to make sure that every expert would understand the purpose, the function and objective of the respective KPIs.

| |
|---|
| On time del. to committed date |
| Del. performance to req. date |
| On time delivery from supplier |
| Total coverage time |
| Perfect order fulfilment |
| Order fulfilment cycle time |
| Upside SC flexibility |
| Upside SC adaptability |
| Downside SC adaptability |

Figure 3:
Evaluated KPIs for SCF Measurement

Subsequent to that, the experts were supposed to rate those KPIs in a 7-point-Likert-Scale in order to evaluate which of these KPIs is able to measure SCF adequately. To state their opinion whether one of those KPIs is able to give a valid and complete declaration of flexibility in supply chains they had to rate them giving a value from 1 to 7, where 1 meant "not at all" significant to 7 "totally" significant. After that, they had to justify their ratings and bring arguments why the respective KPIs were significant or not. The final question was linked to the hypothesis and asked for the knowledge of existing methods in other companies and required an opinion whether the experts think that any company would have to find an individual solution for the assessment and measurement of SCF. This was followed by an open discussion with the chance to add comments.

*Data Evaluation*

The interviews were analyzed by following three steps, namely data reduction, data display and conclusion. Reducing the data was done firstly by means of transferring the information of interviews in terms of collecting quotes that may be of relevance for this study. Then, those quotes were divided into different categories. Definitions were deductively compared to the ones from the theoretical part. New insights and opinions that were indicated and which might influence on the perception of flexibility and its measurement in supply chains were inductively derived from the eight interviews. In the present case, there was a mix of audio records and field notes as some of the experts wanted to maintain their privacy and only permitted the quotation by making notes. Regardless of the degree of structure or type of instrumentation used, the data needed be captured and put in a format amenable to be analyzed.

## Empirical Findings

*General Understanding of Flexibility*

The evaluation of the first topic group in the expert interviews came to the result that there is a strong tendency towards a common perception in the definition of flexibility in general. 6 out of 8 experts defined flexibility without closer description and introduction as the ability to react and adapt to changes in the environment which is a clear signal of a mutual understanding of the theoretical concept behind simple wording. The rest of the experts had slightly different perceptions but tended into a similar direction by already going one step further specifying that flexibility might require the willingness to change in creating a benefit for the customer. Concerning their personal opinions about the importance of flexibility 7 out of 8 clearly stated that they would consider flexibility as a crucial capability in order to be prepared against unplanned events which in addition requires an appropriate mindset. The last expert mentioned that the necessity for flexibility would depend on the environment and the influence factors giving the example that some businesses are not that much impacted by order fluctuations as others. Evaluating the own environment, the majority tended to rate the grade of flexibility quite high.

*Flexibility in Supply Chains*

The question that asked for different types of flexibility in supply chains generated highly diverse answers. Almost all experts (6 out of 8) valued flexibility coming from their specific professional area. This means that they perceived flexibility in supply chains coming from e.g. purchasing, logistics or sales department without having a broad perspective over all the supply chain functions. The question when they think a supply chain would be flexible polarized. Half of the experts stated that when customer satisfaction is reached a supply chain automatically has been flexible enough to fulfill a given demand. The other half transferred the definition given by themselves to supply chains and concluded that a supply chain would be flexible when it could react to various unplanned influence factors and still maintains the same level of performance.

*Measurement of Flexibility in Supply Chains*

All the given answers were negative with regards to the knowledge of existing performance indicators, tools or instruments from their departments or from former employments which could be used to measure supply chain flexibility. Asking the experts to rate whether one of listed KPIs would be totally precise in respect of measuring SCF they answered inconsistently.

It was observed that none of the listed KPIs reached the highest rating which means that none of the experts considered that a single KPI would be capable of giving sufficient information about flexibility and therefore not being able to measure supply chain flexibility alone without maybe combining it with other KPIs. As single metrics, only the perfect order fulfillment and the upside SC-Adaptability were rated to be a relatively useful tool for the evaluation of the flexibility level in a supply chain. Since the aim of the present study was to find out how flexibility in supply chains can be measured and since the central question of the present research was if there exists a KPI capable of being a benchmark for the assessment this analysis on the theoretical and on the empirical side clearly denies this. As supply chain flexibility is a multidimensional concept with different characteristics and dimensions it led to the conclusion that comparing supply chains in general is very complex and hence difficult to achieve. The analysis further came to the result that measuring SCF could not be done by using only one performance metric.

Based on that, the empirical methodology focused on supporting this assumption by getting profound insights of experts from different supply chain functions. The common understanding of the theoretical concept behind

flexibility was given due to the fact that the consulted experts perceived it with consent as the ability to react and adapt to continuous changes in the environment. What is quite remarkable in this context though, is the fact that every expert perceived flexibility in supply chains strongly from his or her personal view in the supply chain and from the respective professional area. The consideration when a supply chain is flexible can be interpreted as follows: When customer satisfaction is reached in the way of perfect delivery performance (without unusual stocks) a supply chain automatically has been flexible enough mitigating all the disturbance factors while putting the customer in the center of the activities. The fact that none of the experts knew any KPIs or tools to measure SCF can also be interpreted as an indirect confirmation of the hypothesis and supports the conclusion that there hasn't been much information about that issue in the past. The overall feedback leads to the assumption that the theoretical analysis is valid in terms of the multidimensional character of supply chains and the difficulty of measuring flexibility.

Asking the experts to rate the proposed KPIs led to the result that none of the listed KPIs reached the highest rating which means that none of the experts considered a solely used metric to be capable of giving sufficient information about flexibility and therefore not being able to measure supply chain flexibility without combining it with others. The experts further concluded that due to the special characteristics and products combined with the individual structures and supply chain processes every company would have to find a way for itself to measure supply chain flexibility but maybe by using the same approach of finding adequate instruments and methods.

After summarizing the empirical findings, the stated hypothesis cannot be rejected. Critical Reflection and Continuous Scale Optimisation

## Conclusion

Summary:

The present study leads to new insights corresponding to the idea of supply chain flexibility measurement. This paper has contributed to the contemporary research by providing a review of the available literature and by elaborating a new perspective on this topic. The main target was to explore the meaning of flexibility, its dimensions and characteristics and receive insights into possible methods for an evaluation and measurement.

The investigation of the most relevant and recent researches on supply chain flexibility revealed that this subject area is not as far explored as other research areas within SCM. The literature analysis came to the result that measuring SCF is not possible by using only one performance instrument as supply chain flexibility is a multi-dimensional concept with many characteristics that is very complex and difficult to evaluate raising the hypothesis that no single KPI would be able to measure supply chain flexibility except a combination of several KPIs. This work strived to build on the identified situation by conducting an empirical study into the topic of measuring supply chain flexibility. By highlighting the need to investigate the aspect of measurement in SCF empirically this paper has implications for the research methods of following studies. Asking experts different questions about this topic led to the result that they supported the assumption that a solely used metric would not be capable of giving sufficient information about flexibility and therefore not being able to measure SCF without combining it with other KPIs. It was further concluded that due to unique supply chain objectives, individual structures, processes and products every company would have to find a way for itself to measure it considering the inferences from this study. For this reason, it can be stated that a real benchmark model for every supply chain currently doesn't exist.

Limitation:

The methodological approach was due to the topic's complexity and the exploratory character appropriate as there hasn't been comparable researches before. Under the circumstances, considering a given time period, the qualitative approach of using semi-structured expert interviews seemed to be justified. Missing universality makes consecutive research necessary to confirm this result. Nevertheless, taking all aspects of the current study into account, it is rather likely that the stated hypothesis can be confirmed than rejected. These new findings contribute to the existing theory by stating that flexibility as multidimensional construct needs to be assessed with a variety of performance measurements instruments transferred to an individual organization. Future research on that topic should focus on quantitative research on a broader perspective to include different industries and businesses.

Management Application:

Next to theoretical implications, this study also provides a contribution for managers to support them in the decision making regarding flexibility as a tool to mitigate uncertainty in SCM. Increasing SCF helps to reduce the overall impact of supply chain disruptions and will help to increase the overall competitiveness. However, it is always a weighting of the required flexibility versus the available budget. Reducing cost is a major driver in businesses which is why the decision what grade of

SCF should be obtained is always depending on the expenditure that these activities and operations provoke. The costs for achieving SCF must be considered before installing far-reaching actions. It will therefore be recommended to carefully analyze the actual flexibility requirements for the respective supply chain.

## About the Authors

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