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How to Cope with Uncertainty in Supply Chains? - Conceptual Framework for Agility, Robustness, Resilience, Continuity and Anti-Fragility in Supply Chains

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How to Cope with Uncertainty in Supply Chains? - Conceptual Framework for Agility, Robustness, Resilience, Continuity and Anti-Fragility in Supply Chains

Immanuel Zitzmann

Abstract

Globalization and new technologies led to the global and lean supply chains that we see today. But cost-efficiency alone does not create customer value. Goods and services have to be available at the time of demand. Shorter product-live-cycles demand volatility and external disruptions force supply chains to be flexible, adaptive as well as customer-oriented. A literature review identifies different concepts to achieve these abilities. These are: agility, robustness, resilience, continuity management, and anti-fragility. All five concepts try to handle uncertainties but pursue different approaches. At the beginning of the 21st century the idea of an agile supply chain was promoted. The goal is to flexibly react to changes. In contrast resilience aims to overcome problems. Flexibility is also part of robustness. A robust supply chain is supposed to efficiently manage fluctuation within the network. Compared to that, continuity management tries to handle threats. Parts of these threats are demand or production fluctuations put also major disruptions. To create competitive advantages out of these uncertainties is the idea of an anti-fragile supply chain. This paper compares recent concepts for the management and design of future supply chains. It also provides a conceptual framework how the different approaches interact to create synergies. An outlook for future research is also given.

Keywords: supply chain, uncertainty, handling concepts, framework

1. Introduction

Today competition takes place between supply chains, not between single companies (Lambert and Cooper, 2000). This leads to value creating networks. The focus on efficiency and the complexity of global supply chains makes them vulnerable (Craighead, et al, 2007). Not only high risks but also low-probability/high-impact as well as operational uncertainties jeopardize value creation (Klibi, Martel and Guitoni, 2010; Van Landeghem and Vanmaele, 2002; Svensson, 2000). Such dangers are increasing because of shorter product-life-cycles, market liberalization and new technologies. Therefore, management has to figure out how supply chains can be designed and operated without failure (Zsidisin, Melnyk and Gragatz, 2005). Within the literature of supply chain management the concepts of resilient/robust as well as agile supply chains are proposed. This article will look at these ideas to evaluate whether they are appropriate for handling uncertainties or not. In addition, continuity management and the idea of anti-fragility will be considered. The aim of this paper is to define these five approaches and show where differences and synergies lay. To achieve this, the structure will be as follows:

First, supply chain management and uncertainty will be defined. It is followed by the introduction of the five approaches of handling uncertainties in the third chapter. The suggestion for a conceptual framework will be introduced in chapter 4. It also outlines the differences and synergies of the different ideas. The final chapter will be the conclusion.

2. Uncertainty in Supply Chains

Supply chain management is accepted as an important field of study, but still has no single definition. For this paper a combined definition from Christopher (2006) and The Global Supply Chain Forum (Lambert and Cooper, 2000) will be used. According to them, supply chain management is "the integration of key business processes from end user through original suppliers that provides

products, services, and information [...] to deliver superior customer value at less cost to the supply chain as a whole". The goal is to integrate functions and processes of individual departments, locations and firms across companies' borders to reduce costs and increase customer value (Cooper, Lambert and Pagh, 1997). Making decisions under uncertainty is part of every management process. Therefore, it has to be considered in supply chain management as well.

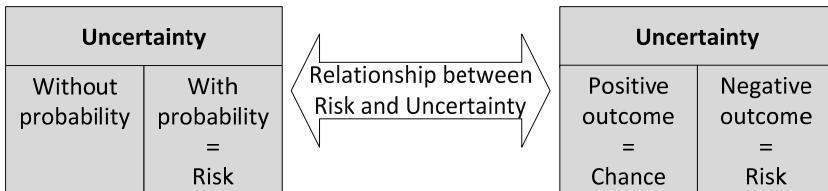


Fig. 1: Differentiation between risk and uncertainty

Uncertainty can be described as the inability to predict something (Milliken, 1987). Often the term risk is used interchangeably with uncertainty. But they are not the same. There are two opinions how they can be distinguished, as can be seen in figure 1. In both cases uncertainty is more than risk. It can be differentiated according to its predictability. If it is possible to quantify a probability of occurrence, it is called risk, if not it is called uncertainty (Knight, 1971). The second approach considers the consequences of uncertainty. If they are positive, they are called chances; if they may be negative, then they are risks (Simangunson, Hendry and Stevenson, 2012). In this paper the second point of view will be taken and the term uncertainty describes both, risks and chances. According to Tang (2006) risks can be operational or disruptive. Both can occur within the supply chain or external (Waters, 2007). Before these differentiations can be applied the concepts will be explained in chapter 3.

3. Handling Concepts in Supply Chains

Resilient and agile supply chains are suggested to handle uncertainties in value creating networks. Robustness is sometimes used as a synonym. To clarify this and also to compare them to continuity as well as to anti-fragile management the five concepts will be introduced in the following paragraphs.

3.1 Agility

In supply chain management literature the definition of Naylor (Naim and Berry, 1999) is used to describe agility (Baramichai, Zimmers and Marangos, 2007; Christopher and Towill, 2000; Mason-Jones, Naylor and Towill, 2000): "Agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place." This understanding was developed in contrast to the lean paradigm (Fisher, 1997), which only works in a stable environment (Mason-Jones, Naylor and Towill, 2000). The agile supply chain on the other hand is designed to cope with changes (Christopher, 2000). The focus is on short-term demand fluctuations as well as changes in consumer behavior. An agile supply chain is able to use these changes to make profit. The idea is to design a network that is flexible and responsive as well as effective (Charles, Lauras and Van Wassenhove, 2010). It is important to note that an agile supply chain will be able to react to demand volatility and delivers a competitive advantage as it is customer focused. But it is not designed to handle uncertainties within the supply chain.

3.2 Robustness

Compared to agility, it is difficult to find a consistent definition of robustness in the context of supply chain management. One reason for this is that the term robustness is often used but not defined at all (Kastsian and Mönningmann, 2011). Vljajic (van der Vorst and Hendrix, 2008) gives an overview of different robustness definitions. In this paper robustness will be understood according to de Neufville, et al. (2004) as the "ability of a system to maintain its operational

capabilities under different circumstances". The supply chain is the system that is considered here. The operational capability that should be maintained is its goal: match demand. The following definition summarizes aspects of different authors (Goetschalckx, Huang and Mital, 2012; Klibi, Martel and Guitouni, 2010; Leung and Wu, 2004; Van Landeghem and Vanmaele, 2002) and describes a robust supply chain as: "A supply chain that is able to match demand and operate on a good cost and profit line in an uncertain environment."

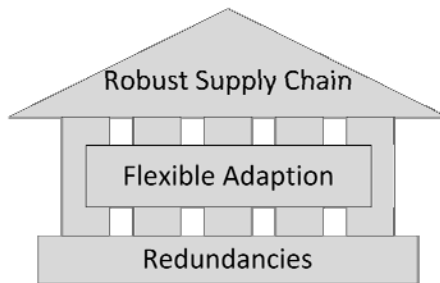


Fig. 2: Levels of a robust supply chain

The reference to costs is integrated to guarantee performance orientated management. Supply chain management literature as well as robust optimization approaches identify two levels of a robust supply chain which are visualized in figure 2 (Pan and Nagi, 2010; Leung and Wu, 2004; Van Landeghem and Vanmaele, 2002; Mulvey, Vanderbei and Zenios, 1995; Kouvelis, Kurawarwala and Gutiérrez, 1992). These are design variables which are fixed and include redundancies. They build the foundation and provide the necessary flexibility for the second stage. Here control variables adjust to the environment and handle uncertainties. Practical tools for both levels have to be identified.

3.3 Resilience

Christopher and Peck (2004) define resilience in the supply chain context as “the ability of a system to return to its original state or move to a new, more desirable state after being disturbed”. The focus of a resilient supply chain lays on major disruptions of the value creating network e.g. earthquakes, shut downs of factories or labor disputes (Sheffi, 2007). Such events have dramatic impact on the supply chain performance as can be seen in figure 3. It shows the impact of the disruption and how long it takes to recover from it. These events are not covered by traditional risk management because they are low-probability/high-impact incidents. The focus of risk management lays on high-probability/high-impact risks.

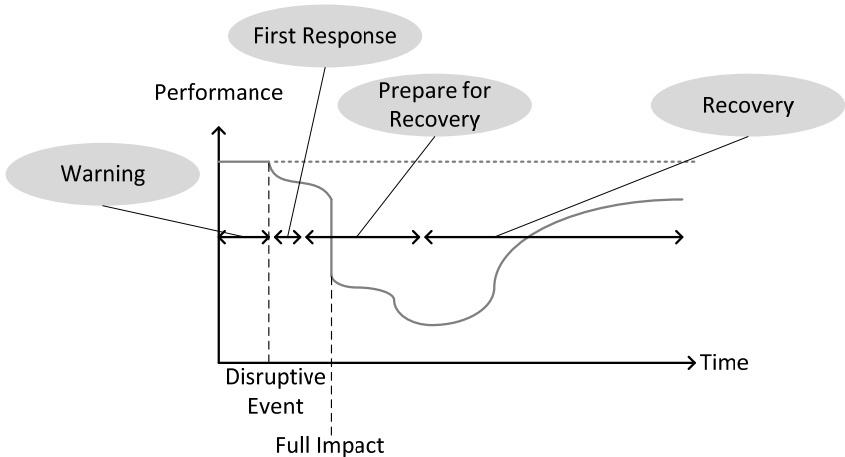


Fig. 3: Impact of disruptive events on supply chain performance (Sheffi and Rice, 2005)

Tomlin (2006) summarizes the different approaches and identifies two major qualities of a resilient supply chain: mitigation and contingency. Klibi (Martel and Guitouni, 2010) uses different terms but have the same intention by describing avoiding/transferring risks and using responsiveness as the two components of a resilient supply chain. In the best case successful mitigation

means that the disruption does not affect the supply chain at all or at least reduces the impact. These strategies have to be executed before an event occurs. Responsive abilities are only applied when disaster hits, but still have to be planned and implemented into a supply chain. Pettit (Fiksel and Croxton, 2010) points out that using all strategies to create a resilient supply chain is not always the best. It is important to consider the trade-off between the cost of resilience capabilities and the vulnerability to low-probability/high-impact events.

3.4 Continuity Management

Business continuity management has its roots in disaster recovery as well as business continuity planning (Herbane, 2010). It is seen as part of the strategic management to handle the impact of crises (Adamou, 2014; Pitt and Goyal, 2004). According to the British Standards Institution (2006), Elliott (Swartz and Herbane, 2010) defines it as: "A holistic management process that identifies potential threats to an organization and provides a framework for building resilience and the capability for an effective response that safeguards the interests of its key stakeholders, reputation, brand and value creating activities." The focus of the business continuity approach lays again on disruptive events or emergencies and how to recover from them (Savage, 2002). As a management concept the integration into an organization, is essential (Elliott, Swartz and Herbane, 2010). But it is only the third step within the business continuity management process that is shown in figure 4. After the initiation, a continuity plan needs to be developed. There are different approaches to the planning process (Zsidisin, Melnyk and Ragatz, 2005; Pitt and Goyal, 2004; Savage, 2004). They range from four to nine steps and are similar to risk management concepts (Zsidisin, Melnyk and Ragatz, 2005). Although the process is designed for an enterprise, the mindset of continuity management today is a supply chain wide.

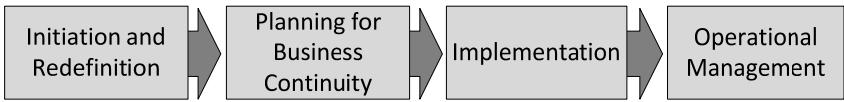


Fig. 4: The business continuity management process (Elliott, Swartz and Herbane, 2010)

3.5 Anti-fragility

The concept of anti-fragility is actually not a concept at all. It is more an idea which is promoted by Taleb (2012). It is based on his recognition of "black swans" (Taleb, 2010). These are disruptive events that have a low probability of occurrence but when they occur they have a large impact on the corresponding system. If the system is anti-fragile it would not lose but profit from the effect. In the context of this paper the system would be the supply chain. The idea of anti-fragility is to create a value network that thrives from an impact as shown in figure 5. Therefore, anti-fragility is defined as "anything that has more upside[s] than downside[s] from random events" (Taleb, 2012). How that should be achieved is not clear. A concept or framework still needs to be developed.

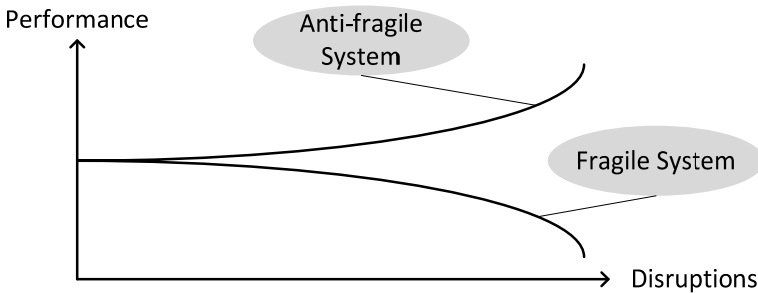


Fig. 5: Performance of anti-fragile and fragile systems

4. Differences and synergies

To interrelate the concepts introduced in the preceding chapter, we will first look at four aspects in order to identify differences and similarities. The

distinction into operational and disruptive uncertainties, introduced in the second chapter, as well as the perception of uncertainties will be the foundation for this analysis. We also analyze whether the concepts handle internal or external uncertainties of a supply chain and whether they work proactively or only after an event occurs. Additionally, we will point out some special perspectives that help building a connectional framework.

4.1 Overlapping and differences of concepts

As explained before, a resilient supply chain is supposed to handle low-probability/high-impact events. In the language of Taleb (2012) these events are "black swans". They are not likely to occur at all, but when they do, the impact is dramatic. Handling them is also the aim of continuity management and an agile supply chain attempts to use them to create competitive advantages. The only concept that does not focus on disruptive events is the idea of a robust supply chain. Here the attention lies on handling operational uncertainty. Uncertainty is perceived as noise that has to be handled to create value for customers and all other members of the supply chain. Therefore, uncertainty can be described as risk, as it is in chapter 2. The same view is taken by the concept of continuity management. Although it deals with disruptive events, uncertainty is considered as a risk for business. The opposite perspective is taken by agile supply chain management and even more by the concept of anti-fragility. The latter sees disruptions as necessary and profits from them. Thus, an anti-fragile supply chain understands uncertainty as an opportunity. The same is true for agility. Changes and uncertainty should be used to create competitive advantages against other, less agile supply chains. Even if resilience is seen as the ability of a system to return to a more desirable state after a disturbance, uncertainties are considered as risks. In the best case they do not occur.

According to Waters (2007) uncertainties can appear within the supply chain or external. Agility means using opportunities in a volatile market. Therefore, this concept only focuses on external chances. Internal processes are not

considered. The contrary can be said about all other concepts. Operational risks which are dealt with by robust management may occur in all internal processes as well as in the supply chain environment. As mentioned in chapter 3, examples for disruptions handled by resilient supply chain management can be earthquakes as well as factory shut downs. Therefore, risks are external as well as internal. This also can be said for the risks which are considered by continuity management. The focus is certainly more on external risks, like the 9/11-attacks, but processes within a supply chain and their vulnerability are considered as well. The same goes for the idea of anti-fragility. Anti-fragility is more a general idea than a developed concept. Nevertheless, it can be said that is reactive.

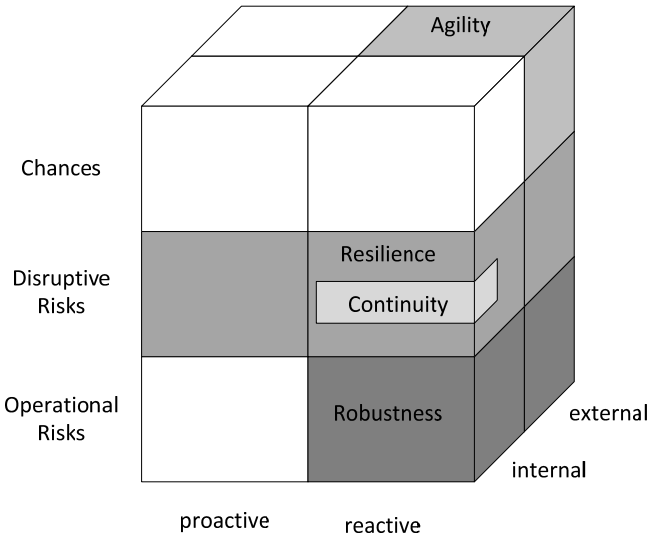


Fig. 6: Differentiation of concepts

As well as all other suggested approaches it has to be planned in advance before it is executed. But there are no actions that are taken before an event occurs. Only after appearance the system reacts. Continuity management is designed in the same way. Agility also tries to react quickly and create

advantages after the incident. A robust supply chain will be able to handle operational risks with little or no adjustments. But even if no actions are necessary, it is still a reactive approach. The reasons for the risks are not tackled in advance. This is only done by resilient management. Here the mitigation of risks before they occur is part of the concept.

Before creating a framework that shows how the concepts work together, three important aspects should be highlighted. They are illustrated in figure 6 together with the previous characteristics. Both, for handling risks and for using opportunities a flexible supply chain is necessary. Thus, the main characteristics of an agile supply chain are its responsiveness and flexibility. Robust planning also enables value networks to react to a wide range of possibilities by establishing flexibility and redundancies. Klibi (Martel and Guitouni, 2010) describes these two factors as the components of responsiveness of a resilient supply chain. So, it can be said that flexibility is part of all three strategies. But even if assets have flexible abilities, they cannot be used if they are busy. Hence, redundancies are needed. Responsiveness is not possible without them.

Continuity management builds resilience. This is mentioned in the concept's definition. It is the management of the responsiveness of a resilient supply chain. Therefore, continuity management can be seen as part of a resilient supply chain.

As already mentioned, anti-fragility is an idea but not a management concept or framework. For reasons of completeness, we will still interrelate it to the other concepts even if it is not a concept for itself. If a supply chain is anti-fragile, it will not be harmed by any kind of uncertainty, it will flourish. So, an anti-fragile system will also have the abilities of agility and resilience. As continuity management is part of resilience management it is also included into anti-fragility.

4.2 Framework of Handling Uncertainty

The purpose of this paper is to identify concepts which can handle uncertainties in supply chains. Therefore, different ideas were introduced. Figure 7 shows how some of them influence supply chain performance. In the bottom graph the variation of supply chain variables can be seen. There is the operational uncertainty every supply chain is exposed to. At three points the graph has a more than business-as-usual fluctuation. Here disruptive events occur. The first and the last are supposed to be internal, the one in the middle is market-driven.

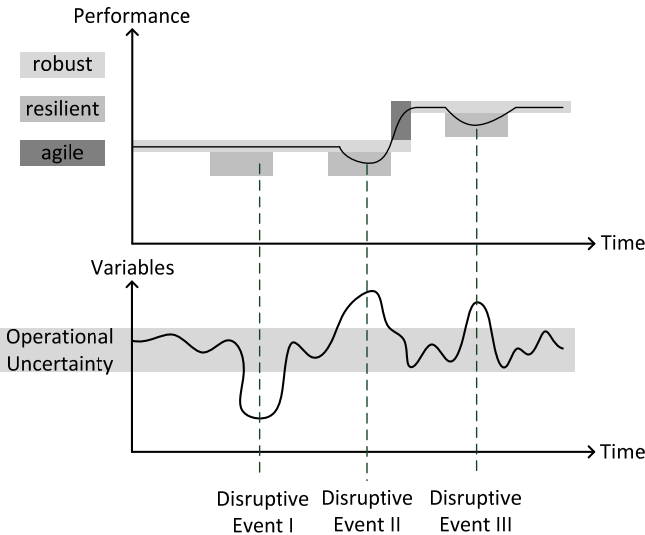


Fig. 7: Influence of robust, resilient and agile supply chain management

The upper graph shows the influence on supply chain performance when robust, resilient and agile supply chain management is executed. Note again that continuity management is also at work as it is part of resilient management. The robust approach accomplishes that operational fluctuations are mitigated so that a steady performance is possible. Resilient supply chain management allows the value network smoothly to return to its desired state after a major

disruption. At the point of the second event this is a higher level of performance. Here chances are used to create competitive advantages.

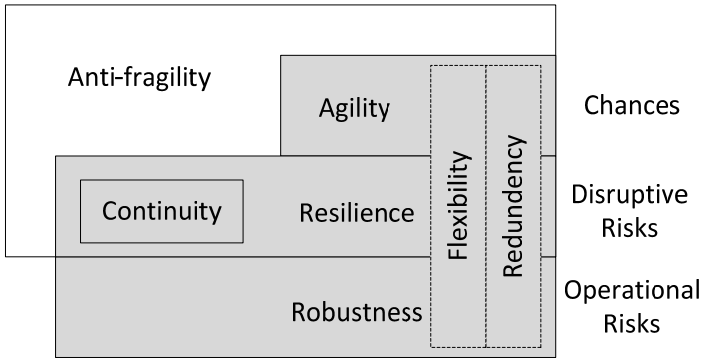


Fig. 8: Relationships between the five approaches

Therefore, it is not only resilient but also agile supply chain management that is at work. From figure 7 we can learn that robustness is the foundation of handling uncertainties. It is necessary to keep the day-to-day-business running and to prevent constant fire-fighting in cases of small fluctuations. But for major disruption, resilience is needed. In the best case, like the first event in figure 7, the mitigation-strategies of the resilient supply chain worked so far as that the fluctuation could be handled by the usual tools of the robust supply chain. In case of the second and third incident, however, reactive actions were needed. The events could not be prevented proactively. This means that resilience is only necessary when low-probability/high-impact events are possible and that it builds on robustness. Agility then is on top of these two concepts. It uses external events to direct the supply chain together with resilience into a more competitive position. Together with the realizations of the previous chapter it is possible to show the relationships of the concepts as they are depicted in figure 8. Redundancies and flexibility are main components of the three supply chain concepts. If an anti-fragile supply chain existed, it would contain agility as well as resilience. Robustness would not be part of it.

5. Conclusion

As the dynamic and complexity of global business increases, different approaches are developed to deal with uncertainties. In this paper, five concepts are introduced. Some coming directly from supply chain research, others prominent in disruption management or controversial discussed. After their presentation and comparison it turned out that the supply chain concepts are the most appropriate. In addition, continuity management could be identified as part of a resilient supply chain. The idea behind anti-fragility is most interesting. Yet, it needs more details to judge its applicability on supply chains and it is questionable whether it is more than a nice idea. Therefore, it currently cannot be used for handling uncertainties in supply chains.

This paper provides a framework for handling uncertainties in supply chains. But it is still just one step on the path to an integrated management concept. For the next steps future research should focus on:

- Identification of practical instruments
- Integration and coordination of the instruments across conceptual
- borders
- Development of a trade-off tool

Literature on the introduced concepts provides a variety of possible instruments to handle uncertainty. But they are often vague from the point of practical application. Here specific guidelines for management need to be developed. At the moment, elements or entire tools are applied in more than one concept. Therefore, it is necessary to look at the instruments from an integrated perspective and not only from the point of view, a single approach has. This is important to avoid conflicts in their application and unnecessary costs. Thus, the trade-off between costs for handling uncertainties and its benefits have to be considered. Here the approach of Pettit (Fiksel and Croxton, 2010) may be the first step.

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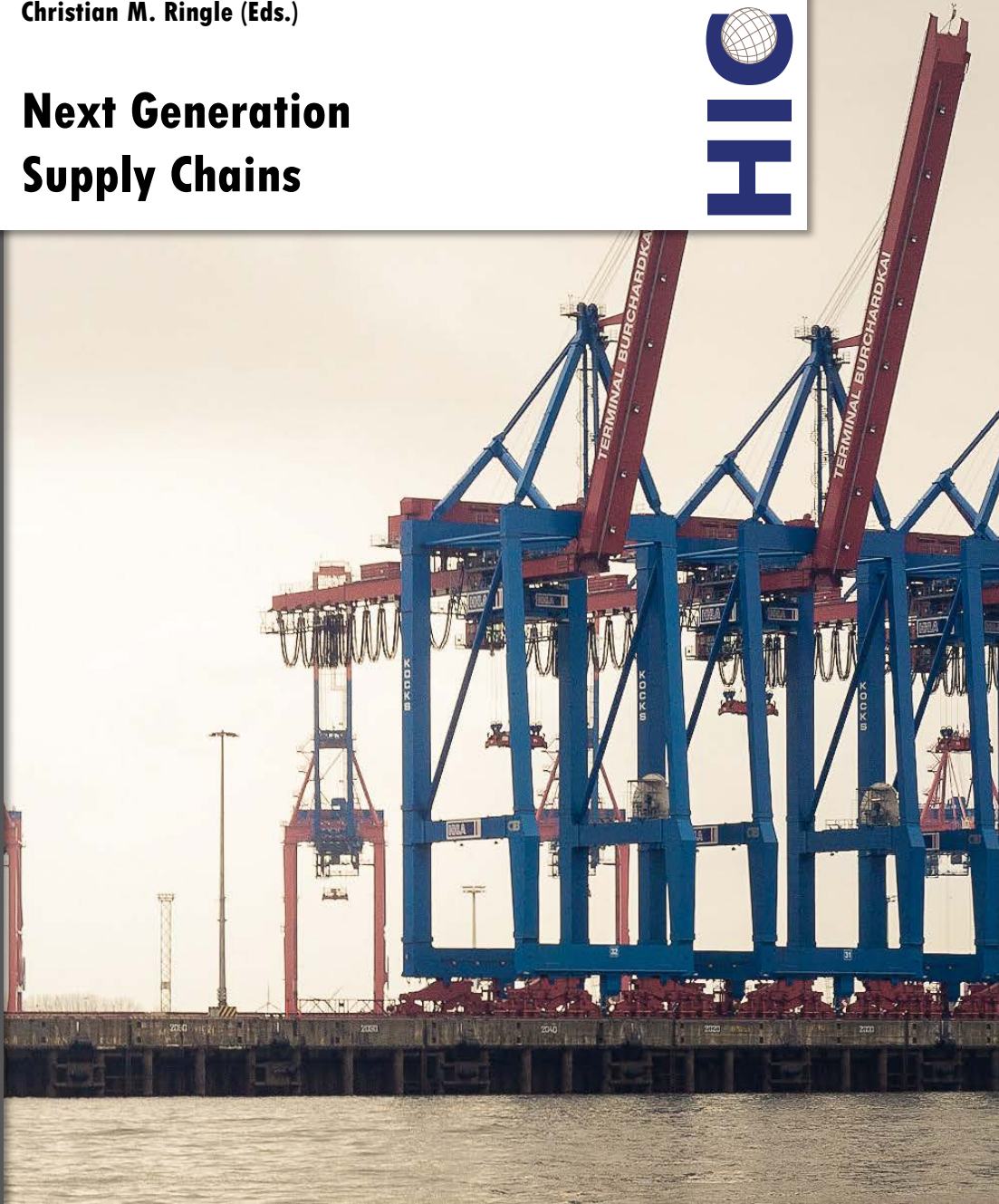
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Preface

Today's business environment is undergoing significant changes. Demand patterns constantly claim for greener products from more sustainable supply chains. Handling these customer needs, embedded in a sophisticated and complex supply chain environment, are putting the players under a constant pressure: Ecological and social issues arise additionally to challenges like technology management and efficiency enhancement. Concurrently each of these holds incredible opportunities to separate from competitors, yet also increases chain complexity and risks.

This book addresses the hot spots of discussion for future supply chain solutions. It contains manuscripts by international authors providing comprehensive insights into topics like sustainability, supply chain risk management and provides future outlooks to the field of supply chain management. All manuscripts contribute to theory development and verification in their respective area of research.

We would like to thank the authors for their excellent contributions, which advance the logistics research progress. Without their support and hard work, the creation of this volume would not have been possible. We would also like to thank Sara Kheiravar, Tabea Tressin, Matthias Ehni and Niels Hackius for their efforts to prepare, structure and finalize this book.

Hamburg, August 2014

Prof. Dr. Dr. h. c. Wolfgang Kersten
Prof. Dr. Thorsten Blecker
Prof. Dr. Christian Ringle

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About HICL

Since 2006 the annual conference Hamburg International Conference of Logistics (HICL) at Hamburg University of Technology (TUHH) is dedicated to facilitate the exchange of ideas and contribute to the improved understanding and practice of Logistics and SCM. HICL creates a creative environment which attracts researchers, practitioners, and industry thinkers from all around the world.



Innovation is increasingly considered as an enabler of business competitive advantage. More and more organizations focus on satisfying their consumer's demand of innovative and qualitative products and services by applying both technology-supported and non technology-supported innovative methods in their supply chain practices. Due to its very characteristic i.e. novelty, innovation is double-edged sword; capturing value from innovative methods in supply chain practices has been one of the important topics among practitioners as well as researchers of the field.

This volume, edited by Thorsten Blecker, Wolfgang Kersten and Christian Ringle, provides valuable insights into:

- Innovative and technology-based solutions
- Supply chain security management
- Cooperation and performance practices in supply chain management

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