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The Imbalance of Supply Risk and Risk Management Activities in Supply Chains: Developing Metrics to Enable Network Analysis in the Context of Supply Chain Risk Management

The Imbalance of Supply Risk and Risk Management Activities in Supply Chains: Developing Metrics to Enable Network Analysis in the Context of Supply Chain Risk Management

Christian Zuber, Hans-Christian Pfohl and Ulrich Berbner

Abstract

From a supply chain management point of view, the flow of goods in a supply chain can be viewed as a network of goods-exchanging actors (Carter, Ellram, and Tate, 2007; Gomm, and Trumpfheller, 2004). While supply chain management activities include requirements-planning and the ordering of goods in value-added networks, activities in supply chain risk management are dedicated to the prevention of possible shortages and their negative impacts. Due to limited resources, risk management activities are usually focused on the most critical goods (Wente, 2013; Zsidisin et al., 2004). This leads to the assumption that for less critical goods, the effort for risk management activities deviates from the actual risk management demand. In order to identify these imbalances and network-related effects, metrics are developed in this paper to measure the existing level of efforts of risk management activities and the level of supply risks concerning the different supplier-buyer relations in a supply chain. In order to integrate the metrics and to locate the need for further risk management activities in a supply chain, measures of network analysis are used.

Keywords: supply chain risk management, risk metrics, supply risk, network analysis, structural holes

1. Introduction

Supply chains have become more vulnerable due to enlarged supply chain complexity and the increased occurrence of natural and man-made disasters over the past years (Munich Re, 2012; Zentes et al., 2012). Among the developments causing increased complexity are globalization (Blecker and Kersten, 2006) as well as concepts which are supposed to facilitate lean supply chains, such as just-in-time (Zsidisin et al., 2005) or single and dual sourcing approaches (Wagner and Bode, 2006). The increased severity of potential risk sources combined with the growing vulnerability of supply chains leverages the negative consequences in case risks do occur (Christopher and Peck, 2004; Jüttner et al., 2003). There is empirical evidence proving that increased supply chain vulnerability has a negative impact on supply chain function and efficiency (Tang, 2006) as well as on the financial performance of the supply chain partners (Hendricks and Singhal, 2005).

Despite growing challenges, there are still numerous gaps in supply chain risk management in research and practice (Sodhi et al., 2012). Most risk management approaches focus on a company-internal perspective or consider dyadic supplier-buyer relations in terms of supply risk management (Henke, 2009; Kajüter, 2007). Network-oriented supply chain risk management approaches which integrate information about supply risk and existing risk management activities on different tiers are hardly implemented (Wagner and Bode, 2006).

Due to limited resources, risk management activities are usually focused on the most critical goods (Wente, 2013; Zsidisin et al., 2004). This leads to the assumption that for less critical goods, the effort for risk management activities deviates from the actual demand for risk management. In this paper, metrics are developed to measure the existing level of efforts of risk management activities and the level of supply risks concerning the different supplier-buyer relations in a supply chain. The metrics must be normalized and independent from characteristics of specific supplier-buyer-relations to enable risk-related

network analysis of supply chains. An example is used to illustrate the possibilities of network analysis for research in supply chain risk management and to evaluate the usage of the developed metrics.

2. Operationalizing the Analysis of Supply Risk and Risk Management Activities in Supply Chains

The understanding of supply chain management in research and practice has changed over the last decades. Even though network thinking was beginning to develop in the early 1990s, supply chain management was seen as the management of (single) supplier-buyer relations (e.g. Christopher, 1992; Harland, 1996) and multiple sourcing was seen as an important strategy to reduce uncertainty in purchasing (Puto et al., 1985). But further network-related effects on the supply side were hardly being taken into account. Due to the rising complexity in global value-added networks (Handfield et al., 2013), the importance of considering network-related effects in supply chains is increasing (Trkman and McCormac, 2009). Especially in times of uncertain and volatile markets, short product life cycles and their imperative of fast supply chain adaptations (Kotler and Casoline, 2009), supply chain vulnerability is an important topic for many companies (Christopher and Peck, 2004).

In this context, the localization of supply risks in a supply chain is as important as the knowledge about the impact of risk management effort on different levels of a supply chain. The supply chain in the context of risk analysis can be described by actors as nodes of a network, whereby the ties represent the risk, the effort of risk management activities, or a relation of either of them, respectively. Consequently, in the following two sections an introduction to the understanding of supply chain risk management from the perspective of network analysis is presented, followed by the development of metrics for measuring supply risk on the one hand and efforts of risk management activities on the other hand.

2.1 Supply Chain Risk Management from the Perspective of Network Analysis

In the broad field of value-added analysis, there are good examples of the usefulness of network analysis in management science. For example, Gokpinar, Hopp, and Iravani (2009) have shown that reasons for network vulnerability can be identified using methods and instruments of network analysis in the case of product development. The usage of the general measures related to network analysis, such as centrality or brokerage, also allows the identification of the vulnerable points of a supply chain.

In terms of network analysis, the supply chain consists of a set of actors (companies as nodes). In this context, the ties between the actors can represent the levels of logistics flows (goods, information, financials, rights; Pfohl, 2004) as well as resulting performance characteristics (e.g. supply risk or efforts incurred). Thus, the size of a network (number of actors) and its density (number of existing ties compared to the number of possible ties) represent measures for the vertical integration of an industry or otherwise defined value-added networks. Regarding supply chain risk, a higher size and density means a higher number of failure sources as well as a higher possibility of using counter-activities. Most important in this case is the definition of the network and of the understanding of a supply chain.

In terms of network analysis, by definition a network is not closed, which is also a correct assumption for a value-added network. In differentiation, a supply chain is a more specific definition of relevant ties from the perspective of one actor who is called Ego in network analysis (see Figure 1). Related actors are called Alter. An Ego acts in different supply chains, which in sum form a supply network. Such a differentiation allows the inclusion of network-related effects in supply chain risk analysis, which the broad discussion of supply risks in supplier-buyer relation cannot afford to do. Network analysis allows the combination of analysis of the whole value-added network and of supply networks or single supplier-buyer relations. Block modeling (Ferligoj, Doreian, and Batagelj, 2012; White et al., 1976) to identify groups of actors with specific

grades of vulnerability in the value-added network is only one possibility for network analysis in supply chain (risk) management out of plenty other analysis possibilities (Hanneman and Riddle, 2012). The challenge is to identify the correct meaning of the different measures of network analysis in terms of supply chain (risk) management.

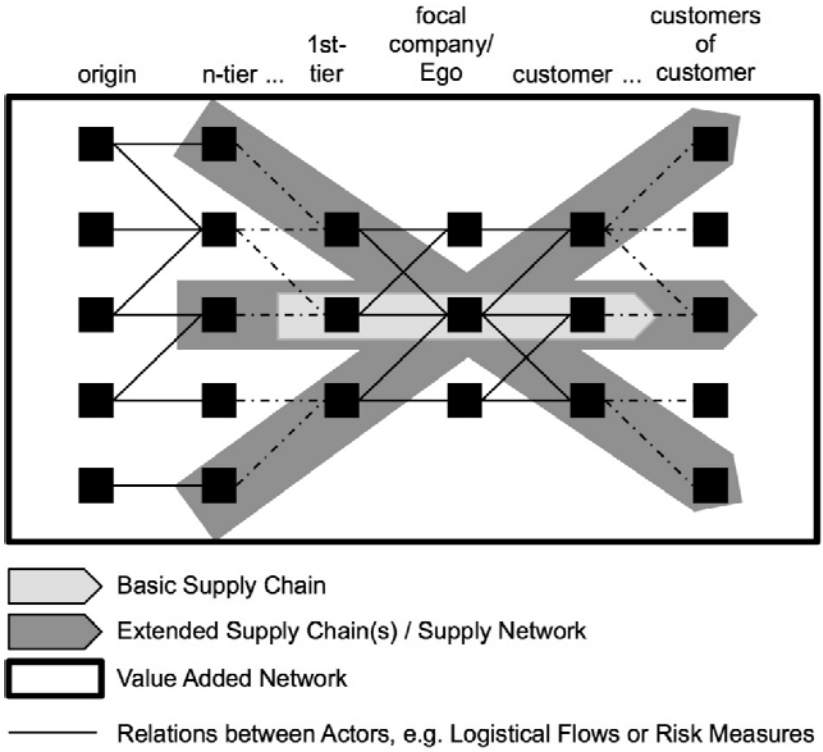

Fig. 1: Differentiation of Supply Chain Definitions

In this paper, we concentrate on structural hole measures to demonstrate the benefit of network analysis for supply chain risk management. Based on structural holes in a network, the status of each actor can be defined. For supply chain risk management it is an advantage to know about weak actors in

the value-added network or to identify indirect dependencies on second-, third-, or fourth-tier suppliers. Measures to identify structural dependencies of actors in a supply chain are necessary to identify the demand of management and further activities (e.g. Carter, Ellram, and Tate, 2007).

According to the structural hole theory by Burt (1992), the advantage of an actor in a network is based on its control over the spread of goods or services between him as an Ego and his Alters as well as between the Alters. “A structural hole exists where two points are connected at distance 2, but are otherwise separated by a long path.” (Scott, 2013: 87). An actor that bridges such a structural hole has a position of advantage – or, in other words, he might constrain the other actors. The measures for structural holes developed by Burt (1992) are based on such dyadic constraints as well as on dyadic redundancy. Dyadic redundancy describes how often a tie between A and B is redundantly existent by considering further actors. In supply chains this would require the involvement of intermediaries. This case is not considered any further. The measure of dyadic constraints describes how an Ego is constrained by Alters based on the existence of specific relations. Thus, this measure is dependent on the size of the network and its density. This makes it difficult to compare networks (or in our case supply chains) with a different structure using the measures of structural hole theory (e.g. Bruggeman, Carnabuci, and Vermeulen, 2003).

Each dyadic constraint will be summed up to the general measure of network constraint. Network constraint describes the total constraint of one actor based on every relation in his neighborhood or in the whole network, respectively. Furthermore, it is necessary to look at the structure of the constraint. Accordingly, the network constraint of an actor can be based on one dominant Alter (high hierarchy) or it can be spread over several Alters (low hierarchy) (Hanneman and Riddle, 2012). Regarding supply chain risk management, the last case indicates risk diversification in the supply chain.

Mostly, the analysis of structural holes in social networks is based on binary data (a relation is present or not) (Hanneman, and Riddle, 2012), even though

the analysis of weighted relations is also possible. We will demonstrate in chapter 3 that in case of supply chain risk management, weighted relations must be taken into account. Hence, adequate metrics of supply risk and risk management activities in supply chains are necessary. Such metrics will be developed in the next section.

2.2 Supply Chain Risk Management: Metrics and Activities

In research and practice, various definitions of the terms risk and supply chain risk exist (Lipshitz and Strauss, 1997; Pfohl et al., 2010). While risk can be seen as the uncertainty concerning a decision situation (Romeike and Hager, 2009), supply chain risk is often understood as any situation that might have a negative impact on the supply chain function (Wagner and Neshat, 2010). Consequences of the occurrence of supply chain risks are described as supply chain disturbances (short term effect) or disruptions (long term effect) (Pfohl et al., 2010).

Supply chain risk management can be understood as all activities on a technological, personal, and organizational level which are employed to reduce supply chain risks (Kersten et al., 2007). Those activities are often divided into activities facilitating either robustness or resilience of the supply chain (Sheffi, 2005; Sodhi et al., 2012). While activities of robustness (e.g. redundancies implemented by dual- or multi-sourcing approaches) ensure that companies inside the supply chain are able to “buffer” occurring risks, activities of resilience allow supply chain partners to flexibly react to any disturbance or disruption and to return to the original condition after the risk occurred (Sheffi, 2001). In order to become resilient, supply chains implement activities like supply chain wide risk management processes and risk management committees, frequent supplier audits, and activities of (risk) information exchange among the supply chain partners (Kajüter, 2007; Wente, 2013).

Possible sources of risk are usually measured by their potential impact as well as their probability of occurrence (Sheffi et al., 2012). In literature, different

typologies of risk sources do exist (Sodhi et al., 2012). While those typologies vary, the described risk types can be summarized as the types 'supply chain-external' (environmental risks, contextual risks), 'supply chain-internal' (demand risks, supply risks, resource risks, network risks) and 'company-internal' risk (process risks, operational risks, organizational risks) (Christopher and Peck, 2004; Jüttner et al., 2003; Pfohl et al., 2008). These risk types are often interlinked with each other (Pfohl et al., 2011).

Due to the high number and variety of potential risk sources, identifying and assessing those risks in order to define appropriate risk management activities is a complex task. Hence, heuristics are developed that simplify the assessment of supply risks in supply chains (Wagner and Bode, 2008). This is done for example by reducing supply risk to the parameters of product risk or supplier risk (Moder, 2008; Wente, 2013). Transaction cost theory can be used as a theoretical foundation for developing metrics for measuring risk. The transaction's risk can be seen as dependent on factors like transaction specificity, transaction uncertainty, and transaction frequency (Moder, 2008). The character of supply chain transactions usually depends on the supplier and on the product itself. The supplier's specificity is closely tied to its exchangeability. For example, in the automotive industry there are certain first-tier suppliers with key knowledge who cannot be substituted easily. Therefore, supplier specificity increases supplier risk. Also, some suppliers might be used over a long time span and proved to provide high quality products, while others are new and it might not be easy to evaluate their reliability. Hence, supplier uncertainty can increase supply risks. The relation between supplier frequency and supplier risk is less clear than the others. While the frequency with which a supplier is used indicates a higher number of total transactions and implies elevated transaction know-how limiting risk occurrences, the transaction number itself is closely tied to risk probability. So in practice there is a higher need to evaluate this relationship since it might be dependent on the particular situation. Since the dependencies on the product level can be derived in a similar way, they will not be described in detail.

Besides supply chain risks, risk management activities on supply chain level have to be taken into account. Those activities include supply chain collaboration in order to facilitate resilience and the building of robust networks with alternative supply paths and methods of redundancy on corporate level, e.g. safety stock.

Due to the complexity of supply chains, it is impossible for a single party to assess and manage existing risks alone – supply chain cooperation is necessary (Cao and Zhang, 2006). The activities listed in literature can be divided into frequent and infrequent activities (Böger, 2010; Kajüter, 2003; Wente, 2013): Concerning frequent activities, integrated risk management procedures and regular workshops/committee meetings can be installed. Supplier audits can also be performed frequently and information can be shared, e.g. by setting up appropriate IT instruments. Information can be shared about arising risks or about best practices concerning risk management (Kajüter, 2003). Infrequent collaborative activities include the setup of a shared risk management organization, the implementation of risk management methods, and instruments for shared usage as well as initial supplier audits.

Robust networks can support the supply chain risk management by providing alternative supply sources and by making alternative logistics service providers available. By providing this kind of redundancy, companies can react to occurring risks with no or only little harm to the supply chain operation.

To prepare for risk occurrences, companies often use redundancy (corporate robustness) either in safety stock or in production capacity (Jüttner et al., 2003). While those activities are easy to implement they are also costly and in the case of safety stock only allow bridging the gap in cases of disturbances which are strongly limited in their time of occurrence.

An outline of possible risk management activities which can be implemented at the supply chain level is given in Figure 2. In our network-based approach, we will focus on activities in the area of collaboration, since there are only a few research attempts in that area so far (Sodhi et al., 2012).

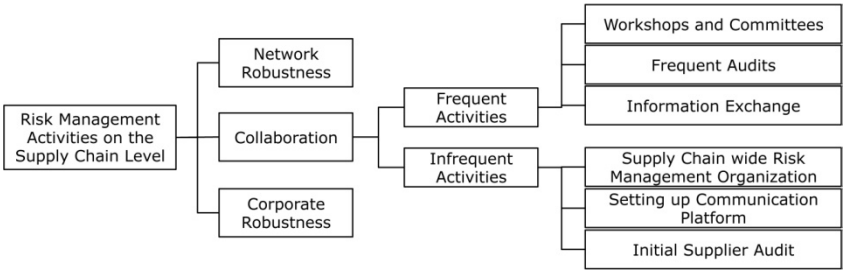

Fig. 2: Risk Management Activities on the Supply Chain Level

Based on the metrics derived and described above, we propose the following model (see Figure 3):

A supply chain's performance can be measured by the three factors shown in Figure 3 (Wieland, 2012). Empirical research has shown that supply chain performance is related to collaborative risk management activities (Wieland, 2012). Factors like product risk determine the level of risk management effort that has to be applied (Wente, 2013). Hence, a metric to calculate the adequacy of risk management collaboration depends on the supply risk on the one hand and on the risk management activities on the other hand.

In order to derive a metric which describes the adequacy of risk management collaboration, we assume that the level of collaborative risk management activities are proportional compared to the level of supply risk. While the supply risk of a supplier S providing product P to recipient R can be described by $Risk_{SRP}$ the related collaboration effort can be described by Col_{SRP} ... In order to achieve comparability of activities and risk levels, we normalize both metrics on a fixed interval, e.g. the [0,1] interval.

This yields $RiskN_{SRP} = \frac{Risk_{SRP}}{\max(Risk_{ijk})}$ and $ColN_{SRP} = \frac{Col}{\max(Col_{ijk})}$. Based on these metrics, a ratio metric can be defined in order to measure the adequacy $ARat_{SRP}$ of implemented risk management efforts. The ratio metric reflects the assumption of a proportional relation between the level of collaborative risk management activities and the level of supply risk:

Ratio metric: $ARat_{SRP} = ColN_{SRP}/RiskN_{SRP}$

The derived metric will increase monotonically if the adequacy of collaborative risk management activities increases. As stated above, risk management research shows that determining risk management activities and aligning those activities with existing risks is not easy. In practice, risk management activities are often only introduced for high-level supply risks (Sheffi, 2005).

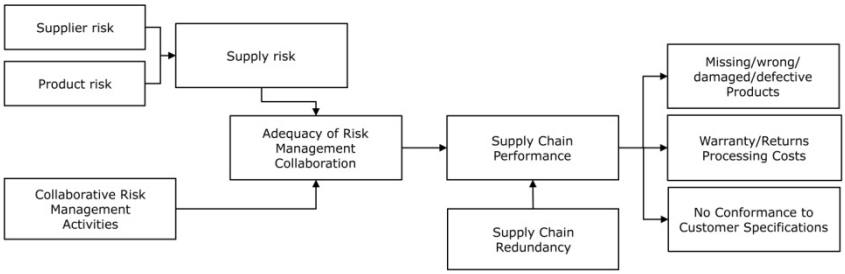

Fig 3: Risk Management Activities, Supply Risk, and Risk Management Performance

This implies that there are often no risk management activities implemented for low-level supply risks as well as for medium-level supply risks. While the decision to not implement activities concerning low-level risks might be adequate, a qualitative evaluation of expert interviews in automotive industry has shown a misfit concerning the effort of risk management activities at medium-level risks. This results in an U-shaped graph when plotting $ARat_{SRP}$ over $RiskN_{SRP}$ (see Figure 4).

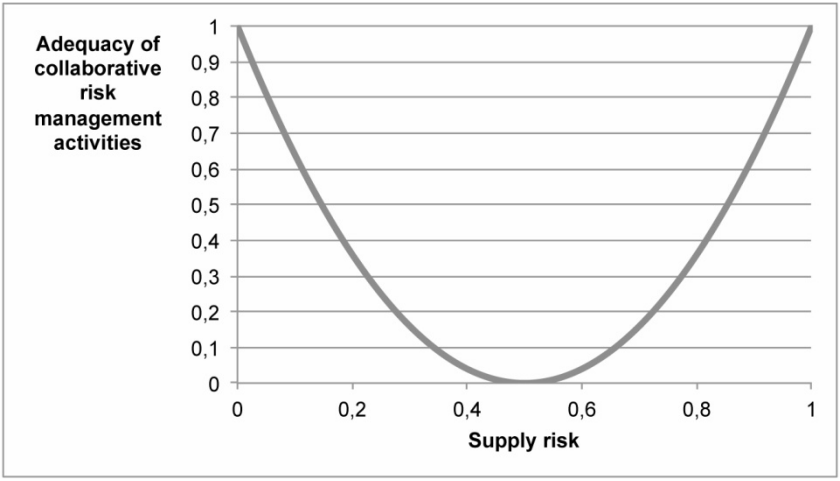

Fig. 4: The U-shaped Relation of Adequacy of Collaborative Risk Management Activities and underlying Supply Risk

3. The Usage of Risk Management Metrics in Network Analysis

In the following, the developed metric will be evaluated based on an example from the automotive industry through network analysis. Three general questions are of main interest:

1. Which network-related effects in a supply chain can be identified through using risk management metrics in network analysis?
2. Why should the effort for risk management activities be considered?
3. How stable are measures of network analysis regarding different types of metrics?

3.1 A fictitious Supply Chain of the Automotive Industry

In the automotive industry, the OEM usually represents the focal supply chain company, which sources critical components from its first-tier suppliers. In our example, the OEM CarManu (O1) is supplied with cockpits from CoreSup (S2).

CoreSup is the single supplier for cockpits for a certain car type. It is supplying CarManu just in sequence. Hence, the product sourced from CoreSup is critical, because it is a central part for assembling the car (see product risk O1-S2 in Table 1). The supplier itself is weighted with a high supplier risk, too, because no other supplier can deliver the cockpits for that specific type of car (see supplier risk O1-S2 in Table 1). Because of this above-average supply risk, the OEM CarManu and CoreSup invest high effort into collaborative risk management activities (see Col_{SRP} in Table 1). CoreSup itself sources electronic modules following a dual sourcing approach from the two suppliers LowWageCorp (S4) and StableCorp (S3). While the product itself has low risk, LowWageCorp is of high risk but offers cheaper prices, while StableCorp is of low risk but offers above-average prices. Both second-tier suppliers, LowWageCorp and StableCorp, have to source the same microchip from the supplier SemiCon (S5). Because the microchip is not a central part for the product offered, but SemiCorp cannot easily be substituted, the overall supply risk seen from LowWageCorp and StableCorp is above average (see $Risk_{SRP}$ for S3-S5 and S4-S5 in Table 1). In order to deliver the products with cheap prices, LowWageCorp cannot invest much in collaborative risk management activities, neither on sourcing nor on distribution side.

While the given example is fictitious, it does very well represent actual automotive supply chains where the OEM often does not know where its second-tier or even first-tier suppliers source their materials from. Furthermore, the fictitious supply chain meets the assumption of a u-shaped interrelation between the adequacy of collaborative risk management activities in supply chains and the normalized supply risk.

Supplier-Buyer-Relations	O1-S2	S2-S3	S2-S4	S3-S5	S4-S5
$Product\ risk$	7	2	2	3	3
$Supplier\ risk$	7	2	5	6	6
$Risk_{SRP}$	7	2	3,5	4,5	4,5
Col_{SRP}	7	2	1	3	2
$ARat_{SRP}$	1	1	0,29	0,67	0,44
$ASub_{SRP}$	1	1	0,64	0,79	0,64

Tab. 1: Levels of Supply Risk ($Risk_{SRP}$) and Collaborative Risk Management Effort (Col_{SRP}) in the fictitious Supply Chain (where 7 represents high and 1 low criticality/risk/effort) and the resulting Weights $ARat_{SRP}$ and $ASub_{SRP}$ (relevant for section 3.2.3)

3.2 Risk Management and Structural Holes in Supply Chains

The point of reference for the following analyses is the weighted example supply chain. The relations between the actors are weighted with the ratio metric $ARat_{SRP}$ (see Figure 5). In the following, network-related effects on the basis of the analysis of structural holes are discussed. Furthermore, through the analysis of structural holes in the supply chain, the necessity of considering the effort of risk management activities will be examined. The software UCINET 6 (Borgatti, Everett, and Freeman, 2002) is used for all analyses presented in this paper. Due to the consideration of overall network-related effects, the analyses are related to the whole network and not only to the 1-step Ego-neighborhood.

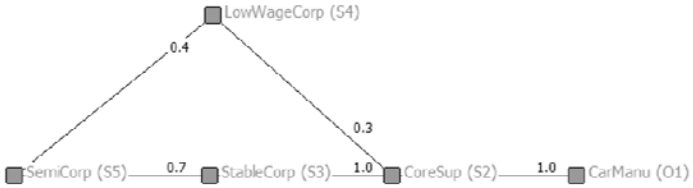

Fig. 5: The fictitious Supply Chain with $ARat_{SRP}$ weighted Supplier-Buyer Relations (printed with Netdraw)

3.2.1 Identifying Network related Effects in Supply Chains

The first question that needs to be answered concerns the relevance of considering weight relations for risk management analysis in supply chains. Figure 6 shows two areas of measures for identifying structural holes: The dyadic constraints present how intense the constraints for each actor as Ego (in the row) of Alters are. In our case, CarManu is mostly constrained by CoreSup, due to the single and only relation that CarManu has. The different intensities of constraints from StableCorp and LowWageCorp due to their role as actors of a dual sourcing concept with different levels of adequacy of collaborative risk management activities ($ARat_{SRP}$) are interesting. Regarding $ARat_{SRP}$, CoreSup is more constrained by StableCorp (0.19) than by LowWageCorp (0.02). This is caused by a higher probability that LowWageCorp cannot deliver (low $ARat_{SRP}$ means higher imbalance and probability of disruptions). In consequence, CoreSup is more dependent on a functioning supplier-buyer relation with StableCorp, which is represented by the higher dyadic constraint measure. The mutual constraints between SemiCorp on the one hand and StableCorp and LowWageCorp on the other hand are caused by the unique position of SemiCorp in the supply chain as the origin of the value chain.

With *ARat* $_{SRP}$ weighted Supplier-Buyer Relations

Dyadic Constraint

		1 CarM	2 Core	3 Stab	4 LowW	5 Semi
1	CarManu	0.00	1.00	0.00	0.00	0.00
2	CoreSup	0.19	0.00	0.19	0.02	0.00
3	StableCorp	0.00	0.36	0.00	0.00	0.16
4	LowWageCorp	0.00	0.16	0.00	0.00	0.36
5	SemiCorp	0.00	0.00	0.36	0.16	0.00

Structural Hole Measures

		1 EffSize	2 Efficie	3 Constra	4 Hierarc
1	CarManu	1.000	1.000	1.000	1.000
2	CoreSup	3.000	1.000	0.397	0.241
3	StableCorp	2.000	1.000	0.520	0.107
4	LowWageCorp	2.000	1.000	0.521	0.115
5	SemiCorp	2.000	1.000	0.521	0.117

Fig. 6: Structural Hole Measures with $ARat_{SRP}$ weighted Relations in the fictitious Supply Chain

As mentioned above, the dyadic constraints are summed up as the network constraint measure (see number 3 in section “Structural Hole Measures” of Figure 6). Regarding this measure, CoreSup is less constrained by the other actors and the higher-tier levels are more constrained. In contrast, the hierarchy of the constraints is vice versa. CoreSup is more constrained by only one other actor than the other actors are, even though CoreSup has the most relations (see Figure 6). These different levels of hierarchy are one main point of interest and demonstrate why it is necessary to consider different levels of adequacy of risk management activities. Compared to the results of structural hole analysis for the binary network (no weighted relations are considered), the general network constraints of every actor are nearly the same. But there is no hierarchy given, so that every Ego is equally constrained by his Alters (see Figure 7).

Binary Supplier-Buyer Relations

Dyadic Constraint

		1 CarM	2 Core	3 Stab	4 LowW	5 Semi
1	CarManu (O1)	0.00	1.00	0.00	0.00	0.00
2	CoreSup (S2)	0.11	0.00	0.11	0.11	0.00
3	StableCorp (S3)	0.00	0.25	0.00	0.00	0.25
4	LowWageCorp (S4)	0.00	0.25	0.00	0.00	0.25
5	SemiCorp (S5)	0.00	0.00	0.25	0.25	0.00

Structural Hole Measures

		1 EffSize	2 Efficie	3 Constra	4 Hierarc
1	CarManu (O1)	1.000	1.000	1.000	1.000
2	CoreSup (S2)	3.000	1.000	0.333	0.000
3	StableCorp (S3)	2.000	1.000	0.500	0.000
4	LowWageCorp (S4)	2.000	1.000	0.500	0.000
5	SemiCorp (S5)	2.000	1.000	0.500	0.000

Fig. 7: Structural Hole Measures with binary Relations in the fictitious Supply Chain

Thus, weighted supplier-buyer relations are necessary to identify network-related effects in terms of constraint and to deliver information about the structure of the constraints in a supply chain. A high level of constraint does not need to be critical for an actor. But if in addition the actor is mainly constrained by only one other actor (high hierarchy), he might see a need for action in terms of risk diversification.

3.2.2 The Necessity of Considering Risk Management Activities

The second point of interest is whether the consideration of the imbalance of risk management activities and supply risk leads to different network related effects in the supply chain.

With $RiskN_{SRP}$ weighted Supplier-Buyer Relations

Dyadic Constraint

		1 CarM	2 Core	3 Stab	4 LowW	5 Semi
1	CarManu (O1)	0.00	1.00	0.00	0.00	0.00
2	CoreSup (S2)	0.31	0.00	0.03	0.08	0.00
3	StableCorp (S3)	0.00	0.10	0.00	0.00	0.47
4	LowWageCorp (S4)	0.00	0.19	0.00	0.00	0.32
5	SemiCorp (S5)	0.00	0.00	0.25	0.25	0.00

Structural Hole Measures

		1 EffSize	2 Efficie	3 Constra	4 Hierarc
1	CarManu (O1)	1.000	1.000	1.000	1.000
2	CoreSup (S2)	3.000	1.000	0.416	0.359
3	StableCorp (S3)	2.000	1.000	0.571	0.342
4	LowWageCorp (S4)	2.000	1.000	0.508	0.043
5	SemiCorp (S5)	2.000	1.000	0.500	0.000

Fig. 8: Structural Hole Measures with $RiskN_{SRP}$ weighted Relations in the fictitious Supply Chain

Compared to the point of reference (Figure 6), considering just the supply risk leads to marginally higher constraints of CoreSup and StableCorp (Figure 8) of about 5%. The main difference can be observed in a different hierarchy. In the case of considering supply risk, CoreSup and StableCorp are much more dependent on only one actor, whereas LowWageCorp and SemiCorp have constraints spread in the network. In terms of supply chain risk management, this means a spread of possible disruptions, too: StableCorp might compensate the probability of disruptions on the sourcing and delivery side of LowWageCorp.

Even though this effect is less surprising because of the different characteristics of the used metrics, the shift of the origin of the constraints is interesting. Regarding the dyadic constraints of CoreSup, StableCorp, and LowWageCorp in Figure 8, using $RiskN_{SRP}$ as a metric leads to a concentration on the borders of the supply chain (columns 1 and 5). Hence, considering the imbalance of risk

management activities and supplier risk provides a better basis for the derivation of network-related effects and the need for further risk management activities. Of course, this must be evaluated using a larger set of supply risk and risk management activities in a supply chain. But this result also shows that structural hole measures represent the risk distribution in a supply chain properly (see $RiskN_{SRP}$ in Table 1).

3.2.3 Comparing different risk metrics in Network Analysis

In the analysis of the point of reference, a ratio metric has been used to weight the supplier-buyer relations. To test the stability of the structural hole measures, we introduce a subtractive metric $ASub_{SRP}$:

Subtractive metric: $ASub_{SRP} = 1 - \max\{RiskN_{SRP} - ColN_{SRP}, 0\}$

Unlike the ratio metric that represents a proportion or balance, the subtractive metric assumes a substitution or elimination of collaborative risk management effort through supply risks. In comparison to the subtractive metric (see Figure 9), the ratio metric leads to marginally higher network constraints (3% to 10%). The main difference again lies in the structure of the constraints, where the origins of the constraints of LowWageCorp are evenly spread. This is caused by the balance of the imbalances on the sourcing and delivery side of LowWageCorp (see $ASub_{SRP}$ in Table 1).

The reason for the occurrence of this balance cannot be discussed here due to missing empirical data. But besides this very specific effect, the structural hole measures are very robust and independent from different metrics.

With $ASub_{SRP}$ weighted Supplier-Buyer Relations

Dyadic Constraint

	1 CarM	2 Core	3 Stab	4 LowW	5 Semi
1 CarManu (O1)	0.00	1.00	0.00	0.00	0.00
2 CoreSup (S2)	0.14	0.00	0.14	0.06	0.00
3 StableCorp (S3)	0.00	0.31	0.00	0.00	0.19
4 LowWageCorp (S4)	0.00	0.25	0.00	0.00	0.25
5 SemiCorp (S5)	0.00	0.00	0.31	0.20	0.00

Structural Hole Measures

	1 EffSize	2 Efficie	3 Constra	4 Hierarc
1 CarManu (O1)	1.000	1.000	1.000	1.000
2 CoreSup (S2)	3.000	1.000	0.346	0.061
3 StableCorp (S3)	2.000	1.000	0.507	0.039
4 LowWageCorp (S4)	2.000	1.000	0.500	0.000
5 SemiCorp (S5)	2.000	1.000	0.506	0.031

Fig. 9: Structural Hole Measures with $ASub_{SRP}$ weighted Relations in the example Supply Chain

4. Conclusion

In this paper, the usefulness of network analysis for supply chain risk management has been demonstrated through structural hole measures. Describing structural holes in a supply chain can process the identification of network-related effects on the basis of imbalances of supply risk and risk management activities. The presented example is very promising for further analysis, because the intensity of network constraints proved to be very robust to different metrics. The main benefit of using network analysis is the possibility of locating imbalances in terms of possible supply chain disruptions and the resulting dependencies of other actors in the supply chain, which has been evaluated by the different levels of hierarchy based on different metrics.

Furthermore, the developed metrics represent a first approach to determine the adequacy of collaborative risk management activities. Empirical data needs to

be collected in order to advance the developed metrics and to test their practical applicability and explanatory power. Initially, the model that has been developed will have to be tested and quantified using statistical methods (e.g. factor analysis and correlation analysis) in order to determine the impact of product risk and supplier risk on supply risk on the one hand and to study the mitigating effect of collaborative risk management efforts on the other hand.

In conclusion, a further development of metrics to enable the identification of network-related effects in supply chains is necessary. Even though network analysis seems to be a very promising approach for supply chain (risk) analysis, further research needs to be done to identify relevant and possible fields of application, caused by a different understanding of networks in social network analysis with hierarchically independent actors and supply chains as a hierarchical network due to the different value-adding levels.

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Next Generation Supply Chains

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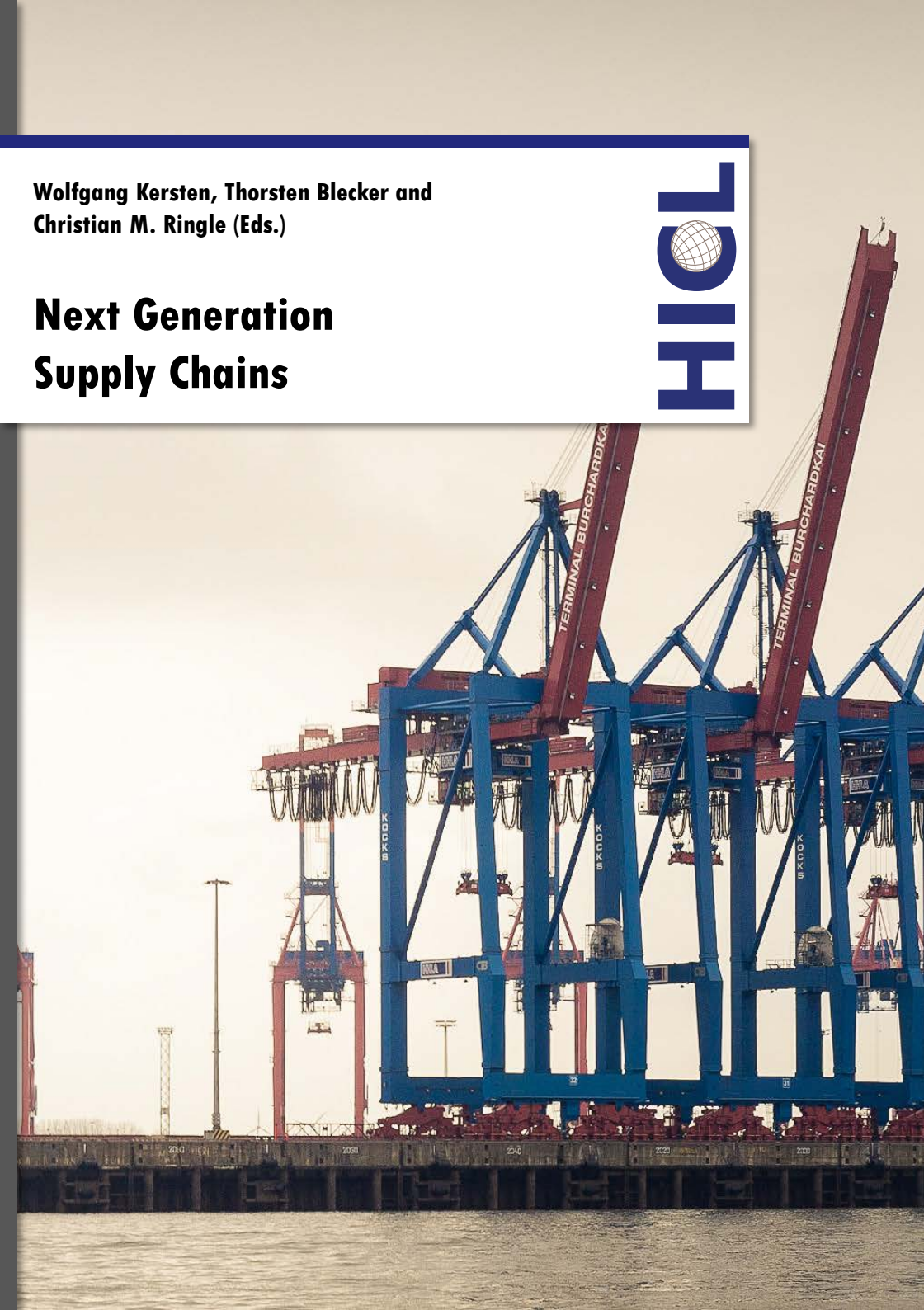

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Next Generation Supply Chains

Trends and Opportunities

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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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