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Continuity Planning in Supply Chain Networks: Degrees of Freedom and Application in the Risk Management Process

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***Abstract*—**Supply chain networks are frequently hit by unplanned events which lead to disruptions and cause operational and financial consequences. It is neither possible to avoid disruption risk entirely, nor are network members able to prepare for every possible disruptive event. Therefore a continuity planning should be set up which supports effective operational responses in supply chain networks in times of emergencies. In this research network related degrees of freedom which determine the options for responsive actions are derived from interview data. The findings are further embedded into a common risk management process. The paper provides support for researchers and practitioners to identify the network related options for responsive actions and to determine the need for improving the reaction capabilities.

***Keywords*—**Supply Chain Risk Management, Business Continuity Planning, Degrees of Freedom, Risk Management Process, Mitigation Measures.

I. Introduction

COMPANIES are frequently forced to cope with disturbances and disruptions caused by natural disasters, acts of terrorism or other unplanned events in supply chain networks. Meanwhile, the literature provides a wide range of examples of such disruptions and its consequences. One prominent example is the case of Nokia and Ericsson. A mutual supplier of the two mobile phone manufacturers lost production capacity after a fire in one of its microchip plants in 2000. The lack of supply with microchips led to significant operational and financial consequences at Ericsson, whereas Nokia was able to react more effectively and hence limited the negative effects [1]-[3]. Nokia's organization and crisis management approach enabled them to identify the potential supply shortage early, gather information about the disruption and tap alternative production capacities [1].

Recently the devastating earthquake near the coast of Japan in 2011 revealed the complexity and vulnerability of global supply chain networks. Numerous companies like Toyota, Apple, Sony, Mazda and Hitachi lost internal production capacity temporarily or were affected indirectly as they lacked of critical supplied components [4].

As pointed out by Peck consequential problems or risks cannot be entirely avoided because they are unknown before they emerge [5]. Consequentially, it is a managerial task to prepare companies for dealing with the unknown. Since the sources of supply chain network disruptions are diverse and many of them unpredictable, firms should concentrate on preparing for the capacity losses which result from disruptive events. Thus, companies may support the rapid recovery of systems and processes in case of emergency without making plans for specific disasters [4].

Despite the reactive nature of recovery actions the response capabilities of companies are partially predefined and limited by the network structure and the processes in the network. Therefore, the preconditions and existing options for action must be thoroughly determined and considered when planning reactive actions for operational network disruptions. With this paper the authors aim to support researchers and practitioners to identify the network related options for responsive actions and to determine the need for improving the reaction capabilities.

In the following section relevant aspects of risk management and business continuity planning are introduced as the basis of this work. In section III the research approach is described before degrees of freedom which determine the options for action of supply network members are identified in section IV. In section V the degrees of freedom are utilized in an adapted risk management process. The paper closes with some concluding remarks.

II. Literature Review

A. Risk Management in Supply Chain Networks

A supply chain network is a set of interconnected supply chains consisting of facilities as network nodes and transportation connections as network edges [6]. The network structure and processes are determined in a network planning process consisting of the steps network design, inventory positioning and resource allocation. The network design describes the physical configuration and infrastructure of the network and serves as the groundwork of inventory positioning and resource allocation [7]. The supply chain network is formed by the organizations linked in the network. Each network member takes a position in the network and manages its relations to other organizations [9],[10].

The effects of unplanned events or developments on supply chain networks can be distinguished into disturbances and disruptions. Disturbances are variations in material or information flow whereas disruptions involve the temporal or permanent removal of edges or nodes in the network [11]

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which leads to an abrupt interruption of material movement [12].

Disruptions are triggered by underlying unplanned events [13]-[16]. The likelihood of the occurrence of the triggering event and the extent of the disruption consequences define the risk. Considering only the negative consequences risks are frequently defined by the dimensions likelihood and potential loss [1],[3],[17]-[22]. Risk management in supply chain networks targets these two dimensions and aims to reduce either one or both. Jüttner *et al.* [23] define supply chain risk management as

"the identification and management of risks for the supply chain, through a co-ordinated approach amongst supply chain members, to reduce supply chain vulnerability as a whole''.

This definition is considered to be appropriate for risk management in supply chain networks since they consist of supply chains.

B. Risk Management Process and Mitigation Strategies

Various authors describe a sequential or cyclic procedure for dealing with risks. Despite varying research focus the procedures commonly contain the steps risk identification, risk assessment and risk mitigation (also: treatment or management) [20], [22], [26], [27]. Some authors add the phase of risk monitoring to the risk management process [3], [21], [24], [25].

In the course of risk treatment appropriate strategies for dealing with the risks are selected. Scholars have increasingly addressed options for risk management strategies in the past [2], [20], [23], [28]-[30]. Efforts for supporting risk management in practice have lead to several risk norms [31], [32]. Raz and Hillson [31] analyze nine risk management norms and summarize that the approaches for risk treatment mentioned in most standards are avoidance, probability reduction, consequence limitation (including recovery and contingency planning), and risk transfer. The limitations of operational consequences through reactive actions in supply chain networks are addressed in this paper. The existing body of literature already provides general strategies for delimiting consequences as enhancing the supply chain network resilience through redundancy and flexibility [4], [30], [33], adding inventory, adding capacity, having redundant suppliers, increase responsiveness [2], increasing recovery and warning capabilities [34], and conducting contingency planning [35], [36]. These strategies show that creating the ability to take actions and the ability to respond to disruptions must not be treated separately. However, the literature lacks of practical approaches to guide researchers and practitioners through the development of measures in the risk treatment phase.

Fig. 1 shows a risk management process applied by Norrman and Jansson [3] which consider the contingency planning and reactive incident handling within the frame of the process.

Fig. 1 Cyclic risk management process considering contingency planning [3]

Risk management in supply chains or networks requires additional coordination effort among network members when passing the process [21],[37]. This may include developing and implementing collaborative network risk strategies [22].

C. Business Continuity Planning in Supply Chain Networks

The goal of business continuity planning (BCP) is to prepare a business for future emergencies [38]. The preparation according to the BCP should ensure continued operations by specifying emergency procedures and resources required [3]. Focusing on preparing for operational responsive actions in cases of supply chain network disruptions the continuity planning in supply chain networks is a fundamental aspect of risk management as well as an element of the broader business continuity management [39].

Responses to a network disruption include restructuring the network. Contrary to normal network formation the response requires an urgent adaptation constrained by time [11]. Therefore, one challenge for network members is to make effective contingency plans and provide the tools to perform urgent adaption [35]. Brock *et al.* [40] present a case study in which the efficiency of an innovative combination of tools in two network disruption scenarios in the field of delivery tour planning is tested and validated. The second challenge is to integrate the contingency planning into the risk management process for an efficient application in practice.

III. Research Approach

The following questions lead this research:

1) What determines the options for reactive actions of supply chain network members in case of a disruption?
2) How can network members prepare for disruption handling?
3) How can network members enhance their business continuity planning considering the existing options for reactive actions?

In this research network related degrees of freedom which determine the options for responsive actions are derived from interview data. Nine in-depth interviews with a total of

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fourteen interviewees were conducted. The interviewees are experts in the fields of logistics, supply chain management and general management with several years of professional experiences in different industries including the automotive industry, mechanical engineering industry, logistics services, retail, and consultancy. The interviews were held as semi-structured face-to-face or telephone interviews and were transcribed or recorded in protocols. The interviews included the topics supply chain network related risk management, experiences with disruptions, consequences of disruptions and potential risk management measures.

Focusing on the preparation for and execution of responsive actions the interview data were coded and gradually condensed. The degrees of freedom for responsive actions were derived and brought together in four categories and more detailed sub-categories. The findings are further embedded into a process for the development of measures as part of the common risk management process.

IV. Degrees of Freedom in Business Continuity Planning for Supply Chain Network Disruptions

A. Degrees of Freedom

Degrees of freedom is the term used in this research to describe the options for action of supply chain network members for responding to a disruption in order to mitigate the consequences of the disruption. Each degree of freedom is understood as one dimension in which a network member is able to adapt. Responsive measures are limited by the existing degrees of freedom and may require more than one degree of freedom. Fig. 2 shows the four main categories derived from the empirical data.

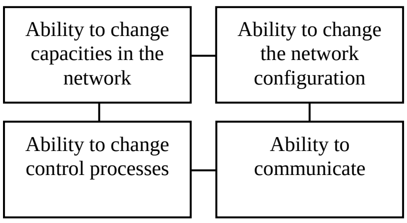

Fig. 2 Categories for critical degrees of freedom in responsive risk management in supply network

B. Ability to Change Capacities in the Network

The ability to change capacities in the network comprises the freedom to increase or reduce implemented capacities in the network. Capacities in the network are function-specific and can be divided into transformation capacities, transportation capacities, transshipment capacities, and storage capacities. Transformation capacity includes capacities to produce goods but also considers any further value adding processes. The ability to change transportation capacities is determined by the ability to adjust the number and the capacity of the means of transport, as well as the transportation frequency. Examples of actions which take advantages of the ability to change capacities in case of a disruption are acquiring additional means of production, shifting personal among functions, using free space as additional storage space, and extending the opening hours for the inbound goods receiving docks.

C. Ability to Change the Network Configuration

Changing the network configuration involves adding or removing elements, nodes or edges. The result is a modified network structure. The changes may include adding or removing elements which affect the capacities for transformation, transportation, transshipment, and storage. Changing the network structure in terms of transportation may comprise using alternative transportation routes, using other modes of transport, and using different means of transport. Above that, the network configuration may be altered by changing the supply relationships in the network. Alternative suppliers, alternative internal inventories or material resources can be tapped in times of disruptions to limit the consequences on the network members. Alternative service providers for transportation services or other additional services may be retained.

The ability to change the network configuration leads to a particularly broad variety of options for action in theory. In practice the abilities to change network structure and supply relationships are restricted by previous strategic and tactical decisions which have lasting effect on the network [7], [9].

Responsive measures using the ability to change the network configurations could be renting additional storage space, obtaining material from an alternative supplier, serving customers using finished goods stock in the network, rerouting in-transit vehicles on the road and executing a special transport via air freight.

D. Ability to Change Control Processes

The ability to change control processes includes the ability to adapt planning, coordination, monitoring, assessment and decision processes. The ability to change planning and coordination processes serves to coordinate internal and cooperative responsive actions after disruptive events as well as to adjust the business processes in order to contain critical functions. This may include changing the organizational structure temporarily, replacing automated planning processes by manual planning processes, intensify cooperative planning processes with business partners, or pulling together employees with specific know-how.

The ability to adjust assessment and decision processes is needed to remain capable of acting and to maintain a high level of efficiency. Potential changes are new assignment of responsibilities, changed rules for prioritizing customer orders, and new rules for allocating scarce resources.

The ability to set up additional or adjusted monitoring processes may increase the transparency and support the disruption related decisions. Such monitoring processes might be required for keeping track of product or service quality during disruptions, examining damages, auditing suppliers, or monitoring early-warning indicators.

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E. Ability to Communicate

The ability to communicate captures the ability of network members to collect and distribute information. Making well-informed decision about responsive actions requires collecting information from internal sources as employees, traffic management systems or ERP-systems and from external sources as suppliers, logistic service providers, and authorities.

Distributing information is necessary to apply decisions, coordinate responses and warn internal and external stakeholders. Responsive actions which require abilities to distribute information are informing customers about disruption consequences, informing the management, and coordinating responsive measures among supply network partners.

The four main categories of degrees of freedom and its sub-categories are shown in Table I.

TABLE I
CATEGORIES OF DEGREES OF FREEDOM IN RESPONSIVE SUPPLY CHAIN NETWORK RISK MANAGEMENT

Category	Sub-category
Ability to change capacities in the network	*Ability to adapt* • Transformation capacities • Storage capacities • Transportation capacities • Transshipment capacities
Ability to change the network configuration	*Ability to use alternative* • Transformation capacities • Storage capacities • Transportation capacities • Transshipment capacities • Inventory (internal) or suppliers (external) • Service providers
Ability to change control processes	*Ability to change* • Monitoring processes • Planning and coordination processes • Assessment and decision processes
Ability to communicate	*Ability to* • Collect information from internal and external stakeholders • Distribute information to internal and external stakeholders

The identified degrees of freedom provide support for determining existing and required abilities for responsive measures. Responsive measures may require more than one specific degree of freedom. As an example, the ability to collect and distribute information can be a prerequisite for the ability to change planning processes. Adapting transformation processes may require adapting the planning processes and hence the communication processes must be tailored accordingly.

V. USING DEGREES OF FREEDOM FOR DEVELOPING MITIGATION MEASURES TO LIMIT DISRUPTION CONSEQUENCES

For the application of the degrees of freedom an iterative process within the risk treatment phase is presented. Fig. 2 shows the process that supports researchers and practitioners in developing appropriate mitigation measures that reduce the potential impact resulting from a supply chain network disruption.

Mitigation measures can be distinguished into proactive and reactive measures. The first are implemented in order to create degrees of freedom, whereas the latter use degrees of freedom in case of a disruptive event. Developing operational measures to react on supply chain network disruptions is part of contingency planning.

Basis for the treatment of risks is the data gathered during the risk identification and assessment. The proposed process is conducted for each relevant risk. A common approach for analyzing and assessing disruption risks and mitigation measures is the scenario technique [41]. Such disruption scenarios have to be proved valuable to get comprehensive insights to the consequences of the triggering event and potential effects of mitigation measures [42]. An important dimension of risk is its potential causal pathway [43]. Therefore the logical separation of the triggering event, the disruption and its potential consequences is essential for the scenario-oriented analysis [41].

For ensuring an efficient disruption risk treatment the existing options for action must be identified. This is done by determining existing degrees of freedom. Based on these, potential mitigation measures are developed. For the selected disruption scenarios, the way the developed reactive measures affect the potential disruption consequences is tested.

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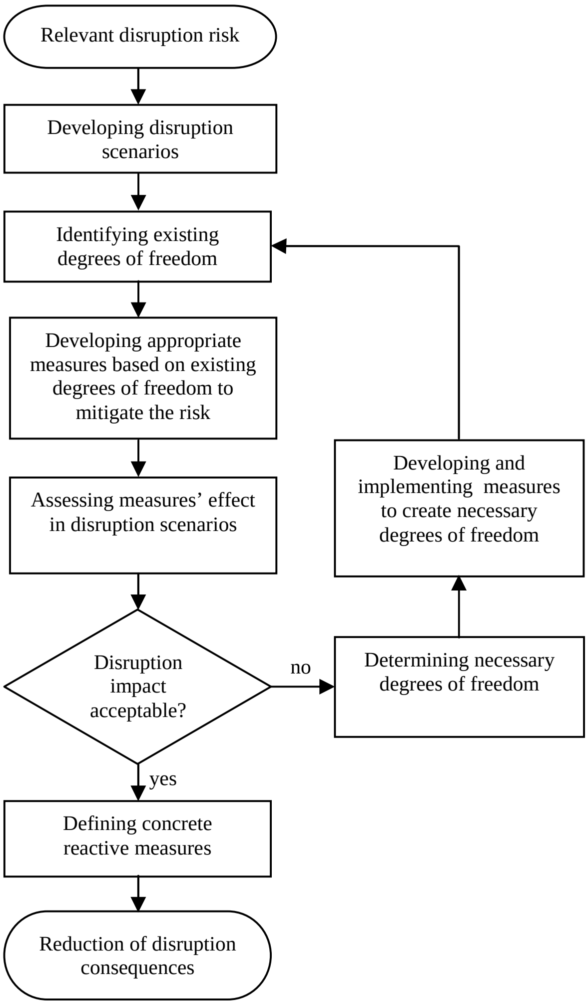

Fig. 3 Developing mitigation measures as part of the risk management process

In case of an acceptable disruption's impact in the network, a concrete reactive measure or sets of reactive measures are defined that will be implemented when the disruption occurs. Otherwise, the missing degrees of freedom that are necessary to define more appropriate measures need to be determined. Consequently, proactive measures need to be implemented to create these degrees of freedom.

Having created additional degrees of freedom, more options for action to reduce the potential impact exist. This closes the loop of Defining appropriate measures with the help of degrees of freedom to mitigate the impact of disruptive events in supply chain networks.

The proposed procedure implies that developing mitigation measures in the risk management process includes determining reactive actions as well as creating the options for action through proactive measures. The examples of proactive and reactive measures relating to the main categories of freedom in Table II illustrate the relation between the two types of measures.

TABLE II
EXAMPLES FOR PROACTIVE AND REACTIVE MEASURES

Degrees of freedom	Proactive Measure: Creating degrees of freedom	Reactive Measure: Using degrees of freedom
Ability to change capacities in the network	Train employees to be capable of executing different operations	Shift personal to increase required production capacity for overcoming supply shortage
Ability to change the network configuration	Secure access to additional capacity at an alternative trans-shipment point in case of emergencies with logistics service provider by contract	Reroute transports using an alternative transshipment point
Ability to change control processes	Determine members and competences of task forces	Appoint a task force for coordinating disruption response activities
Ability to communicate	Implement early warning mechanisms in IT-system	Collect warning signals and distribute warning information to employees

VI. CONCLUSION

It is neither possible to avoid the occurrence of every unplanned event triggering a supply chain network disruption nor are companies able to prepare for every particular disruption. Hence, planning and preparing for potential capacity losses should be part of each company's risk management initiative.

In this paper the authors depict the degrees of freedom which are relevant for identifying the options for responsive actions. Under consideration of existing degrees of freedom reactive measures can be developed and requirements for further options for action determined.

The proposed categories for degrees of freedom and the adapted process for the development of mitigation measures ought to serve practitioners and researchers to systematically develop risk mitigation measures considering the capabilities of the company in the network. The common concepts of the risk management process and business continuity planning are applied and extended by integrating the developed degrees of freedom in the risk treatment phase.

The degrees of freedom presented in this paper are derived from interview data. Therefore, the generalizability of these findings is limited. Further work should be done to apply and test the degrees of freedom as well as to identify additional tools and methods to support the proposed process for developing mitigation measures.

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