Supply Chain Safety: A Diversification Model Based on Clustering

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Abstract. The issue of supply chain safety has received broad attention which has led to a wide range of methodologically different approaches; for a survey see (Pfohl, Köhler & Thomas, 2010). The present paper introduces a novel quantitative algorithm that provides a multiple covering of the commodity graph via constrained clustering. In fact, we construct supply chain components in the overall supply network of a company, each being able to account for some percentage of the company's overall production. They are all isomorphic to and can hence be viewed as different realizations of the commodity graph which are most independent with respect to known hazards. Consequently, suppliers (of each level) are assigned to supply chain components so as to minimize the probability for a total (or severe enough) breakdown. The basic new model is given in detail, complemented by an outline of more involved ramifications that are able to deal with realistic scenarios. Also, we give computer simulations that indicate the favorable behavior already of our basic model in terms of risk reduction.

1 Introduction

The 9.0 earthquake followed by a tsunami that hit the east cost of Japan on March 11, 2011, and the subsequent nuclear fallout were a tremendous humanitarian disaster. Naturally, it also had severe direct regional and national economic consequences. There are, however, also substantial global implications due to the breakdown of global supply chains. A large German company estimated its related economic loss to more than 200 million Euros. While the total worldwide economic effect of Japan's recent natural catastrophe is still not fully accounted for, the effect of the much smaller '*Albuquerque accident*' on March 18, 2000, for Ericsson has been well analyzed; see

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e.g. (Norrman & Jansson, 2004). A small fire at a sub-supplier's factory was made responsible for a loss of about 400 million US-Dollars and was at least partly decisive for the company's withdrawal from selling mobile phones. Nokia was also affected by the fire, but in contrast to Ericsson was able to obtain the component through alternative sources. Hence robustness of supply chains against external disruptions is not only of theoretical interest. As a matter of fact, total dependence on one supplier or sub-supplier may lead to enormous economic losses.

Consequently, various qualitative and quantitative methods for increasing supply chain safety have been developed, ranging from fuzzy set theory, see e.g. (Yang, Wang, Bonsall, Yang & Fang, 2005) to neural network approaches, see e.g. (Teuteberg, 2008). For a critical review see (Klibi, Martel & Guitouni, 2010).

There are various papers on the conceptual and normative level of the management of supply chain risks, see e.g. (Jüttner, Peck & Christopher, 2003) or (Peck, 2005), while others use qualitative research methods, see e.g. (Svensson, 2002), (Zsidisin & Ellram, 2003), (Jüttner, 2005) or (Zsidisin & Wagner, 2010). There is, however, need for quantitative methods. In particular, (Wagner & Neshat, 2010) emphasize that "in line with the frequently cited business wisdom 'You can't manage, what you don't measure' supply chain managers need support in quantifying and thus mitigating supply chain [risks]." Moreover, a look into the relevant (i.e., purchasing-, logistics-, and SCM-related) literature shows that – with regard to the use of quantitative research methods – only few publications can be identified which choose simulations and mathematical models as an alternative to large-scale surveys. In analyzing various quantitative models that deal with supply chain risks, (Tang, 2006a), for instance, points out that the existing quantitative models primarily focus on managing operational risks rather than on disruption risks. Consequently, he identifies the need for research on the demand and supply process, on the appropriate objective functions and on appropriate supply, demand, product, and information management strategies. (Deane, Craighead & Ragsdale, 2009) develop a model which allows organizations to mitigate two key global risks – environmental and density risks. The model is based on the idea that by adjusting the values of the underlying model parameters the procuring organization can limit its potential exposure to individual supplier failures and directly control the number of sources of supply. Thus, organizations will be able to employ and take advantage of sourcing strategies while simultaneously reducing the negative effects of environmental and proximity types of disruptions by increasing geographic dispersion of the supply base and selecting suppliers from different regions. (Ravindran, Bilsel, Wadhwa & Yang, 2010) develop two different types of multi-criteria supplier selection models incorporating supplier risk and apply them to a real organization. The risk-adjusted supplier selection problem is modeled as a multi-criteria optimization problem and is solved in two steps. Step 1 serves as a pre-qualification, where a large set of initial suppliers is reduced to a smaller set of manageable suppliers using various multi-objective ranking methods. Step 2 focuses on the allocation of order quantities among the short listed suppliers by using a multi-objective optimization model. Methods from stochastic optimization are also used in (Santoso, et al., 2005), (Goh, et al., 2005), and (Schütz, et al., 2009).

Of course, quantitative strategies require quantitative information on the structure and the (potential) dynamics of the underlying supply network but also