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A Simulation-based Approach to Risk Assessment and Mitigation in Supply Chain Networks

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Abstract

We present in this paper a simulation-based approach to evaluate the risk associated with supply chain disruptions caused by failures in some supply chains nodes and measure the impact of such disruptions on supply chain key performance measures (KPIs) of interest. The proposed framework enables analysts and managers to repeatedly assess the risk to their supply chains based on various simulated scenarios and identify the most critical nodes whose disruption will have the highest impact on the KPIs of interest. As a result, companies can focus on the most critical supply chain assets and develop targeted mitigation plans that minimize their risk.

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*Keywords:*DEMO Methodology, ontological modeli, enterprise modeling, agents simulation

1. Introduction

Today's consumer products have reached an unprecedented level of complexity. A common product such as a smartphone is made of hundreds of parts sourced from almost as many suppliers. Furthermore, in line with the trend of globalization, businesses have become very astute in sourcing and setting up production units at the most cost-effective location, geographical distance being just one factor among many. This has stretched supply chains to the extent that a natural or geopolitical disruption can see its effects propagated thousands of kilometers away.

This situation, in conjunction with the tense competitive environment in which businesses operate, has made supply chain risk a major concern. As a result, researchers are investigating methodologies and analytical techniques to assess and mitigate risks in supply chains (Tang, 2006).

Modeling and simulation is a well suited method to assess the joint effects of structural and behavioral factors in complex systems. Simulation is thus a natural candidate technique to study the risk performance of complex supply

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chains. The body of work on supply chain risk simulation is growing very fast. Various techniques have been used, including discrete event models (Schmitt, 2009), systems dynamics (Briano, 2010), Monte-Carlo approaches (Jin, Zhuang, & Liu, 2010), and agent based models (Harper, 2012), among other methods.

However, as in most modeling and simulation problems, there is a tradeoff between the level of detail in model conceptualization and the scale that the modeling approach can handle effectively. Most of the simulation approaches proposed for supply chain risk management tend to be complex and overly mired in operational details, to an extent that hinders their applicability to very large cases.

We propose an agent based conceptualization that models the supply chain at a level of abstraction which enables effective assessment of strategic risks and the development of mitigation plans.

Section 2 gives an overview of the conceptual model, introducing the entities, their parameters and the KPIs. Section 3 provides a set of simple scenarios to give some insight on the functioning of the simulation. Finally, section 4 summarizes the contribution and discusses future works.

2. An Agent Based Conceptualization of Supply Chains

A supply chain is a network designed by an organization to match supply with demand in a cost effective way while taking into account different sources variance. This network is composed of nodes which fulfil different functionalities such as production, storage, and distribution, and edges that transfer flows between the latter nodes. These flows are also of different types, including physical, informational and financial flows. While the domain of supply chain risk management is broad and may include issues as broad as fluctuating exchange rates and hedging, in this study, we are mainly interested in risks pertaining to the capability to serve the demand. We thus create a minimalist agent based conceptualization that allows us to represent the essential aspects of a supply chain and to simulate possible disruption scenarios. This section introduces the entities that have been included in the agent based model. For clarity, model entities are denoted in the text as “entity”. The attribute of an entity is denoted as “entity.attribute”.

We consider the product as it goes through the different stages of its elaboration as dictated by the bill of materials. Another consideration, maybe the most fundamental to supply chain risk, pertains to the characterization of demand. Because sourcing, producing and transporting are activities that take time, supply chain managers must have some sense of the demand days and sometimes weeks before it actually occurs. In the vast majority of markets, however, demand is not stable over time. It fluctuates based on different factors such as the strength of competition, sales and promotions, weather and seasonality, most of which are out of the manager’s control. This intrinsic variance in demand makes demand forecasting extremely difficult. The model described in this paper also represents inventory explicitly. In the remainder of this section, we discuss the model at the conceptual level by first discussion the main entities and their attributes, the behavioural functions, and finally the performance indicators.

2.1. Model Entities

- p-referencerepresents the product. It is characterized by its bill-of-materials, that is, a list of trees representing sub-components and their quantity. A p-reference can have more than 1 bill-of-materials, to simulate alternative recipes.

- Forecasted demand, f-demand, is a passive object characterized by the product reference, p-reference, a unique identifier for the product in need, quantity, denoting the quantity forecasted, and time, denoting the forecast window, or time at which this forecasted need will become a firm need.f-demand.quantityis modelled as a probability distribution to represent the observed variation in forecasted demand.

- Firm demand, demand, is a passive object characterized by the product reference, p-reference, and by the quantity demanded, quantity. In the simulation, demand.quantity is obtained by applying an error-rate to the forecasted demand. In the standard case, error-rateis normally distributed and centred on 0 so that the