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A Model for Evaluating Supply Chain Risk

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Abstract

Companies are being forced to adopt practices and structures that will produce high quality, reliable, reasonably priced products with continuously shorter lead times. In order to meet the above goals, companies are utilizing flatter organizational structures and narrower supply chains. Breadth and depth reductions in a firm’s supply base yields fewer alternatives in response to failures. The vulnerability of different supply chain structures is assessed and a model for designing robust solutions under risk is presented.

Key words: Supply Chain, Risk, Network Design, Marketing Channels
Introduction

In an environment where markets and customers are increasingly exemplifying “commodity” type markets and where the demand for greater flexibility and lower cycle times are increasing, firms are re-evaluating their organizational structures and outside relationships for greater competitiveness. The need for leaner, more competitive, organizational alignments forces companies to place a greater emphasis on core competences and the out-sourcing of non-core activities. Prahalad and Hamel (1990) state that an increased emphasis on internal competencies requires a greater reliance on external suppliers to support the organization’s non-core requirements. Gurbaxani and Whang (1991) assert that, as firms reduce their transaction costs, there are strong incentives to reduce the size of the firm and increase the utilization of outsourcing. These trends increase the dependence on outside resources over which the firm has less control. With increased organizational integration and reduced inventory buffers, single point failures could affect all partners within the supply chain. Thus, the firm’s vulnerability to “external events” increases.

Increased global competition has forced organizations to offer low cost, high quality and reliable products. With the adoption of quality driven paradigms, such as Total Quality Management, Just-In-Time, and Lean Manufacturing, organizations began to realize the benefits of strategic and cooperative buyer-supplier relationships. When all organizations in a firm’s supply chain are ‘integrated’ and are acting as a single unified entity it is expected that performance would be enhanced throughout the supply chain (Tan, 2001). Organizations have been re-evaluating their supply chains (both internal and external) and out-sourcing those activities which they consider to be non-core, and as a result, reducing their supplier base (Christopher and Juttner, 2000). The redesign of existing supply chains or coordination
structures and the creation of new ones provide the firm with opportunities for improved product and service delivery at a lower cost (Malone, 1987 and Malone, 1988).

It is believed that increased out-sourcing is generally coupled with a firm’s move to rationalize their supplier base (Christopher and Juttner, 2000). The motivations for this move are partially driven by economics, partially by continuous quality improvement, and partially by the realization that there is a limit to the extent to which multiple supplier relationships can be effectively managed. Every company maintains a variety of different relationship and may not be willing or capable of developing close ties with all parties due the resource intensiveness and the financial risk. They also increase the vulnerability of the involved parties by exposing them to opportunistic behaviors and the potential weaknesses or failures of the other parties. With greater complexity in the supply chain, trust becomes a growing concern and organizations should routinely reexamine their relationships with respect to future strategies and position. In addition, Choi and Krause (2006) found that reducing the complexities in the supplier base may alleviate costs, but that the buying competitiveness of a company may be reduced. They suggest that, by examining the effects of supplier reduction on transaction costs, supply risk, supplier responsiveness and supplier innovation that transactions costs may be lowered, but supply risk may increase with a simultaneous decrease in supplier responsiveness.

**Objectives**

A major issue observed in the reevaluation of the relationships within a supply chain to a firm’s positioning and strategy is the lack of comprehensive, standard measurements with which to base the evaluation. As argued by Weber, Current, and Benton (1991), “given the complexity and economic importance of vendor selection it is somewhat surprising how little attention has been paid in the literature to the application of quantitative methods to vendor selection”. In
addition, Ritchie and Brindlye (2007) developed a framework for supply chain risk management in which they conclude the inclusion of risk management influencers affects management responses to certain situations. They also state that there is a “need for the Operations Research discipline to evolve a more diverse set of risk management tools and approaches to effectively address the diversity of issues and contexts”. Finally, Barry (2004) found that the breadth and scope of supply chain risk has significantly broadened over the past few years.

It is proposed, therefore, that one such standard measure should measure the risk involved with organizations and their supply chains. The objective of this research, then, is to develop a model to assess risk. To this avail, different supply chain structures are investigated and a methodology for evaluating the relative risk associated with different supply chain designs is undertaken to develop a measure of risk, called the risk index.

**Defining Risk**

In order to understand the risk associated with the supply chain failing to deliver the promised good/service, the supply chain structure itself along with subproducts and subservices within the structure needs to be examined. This risk, which we will call the risk consequence(α), can be calculated as follows:

\[
\alpha = \frac{\delta_{\text{replace}}}{\delta_{\text{collapse}}}
\] (4)

where \(\delta_{\text{replace}}\) = the time required for a supply chain to fully replace a given subproduct or subservice, or resolve the disturbance to the product flow, and resume a normal product delivery schedule at the same quality level, and

\(\delta_{\text{collapse}}\) = the time a given subproduct or subservice can fail to be delivered before the supply chain suffers the loss of a critical mass of its market share.
Note that $\delta_{\text{replace}}$ is limited in magnitude to that of $\delta_{\text{collapse}}$ because, at that point, the supply chain will cease to exist. Therefore the range of the consequence score ($\alpha$) is from 0 to 1, where 1 implies the collapse of the supply chain should a failure occur and 0 implies there is no effect (or consequence) of the risk.

For the sake of the study, consequence scores were classified as vital, necessary, or desired. A ‘vital consequence’ score is assigned for subproducts or subservices if there are no substitutes for this item and, should it not be present, there would not be a product or service for the supply chain to deliver. A ‘necessary consequence’ score is assigned for subproducts or subservices in which substitutes do exist, but their usage, with respect to the subproduct or subservice, would significantly reduce the functionality or quality in the product or service being produced by the supply chain. The usage of a substitute product or service could require a redesign in the supply chain’s product or service. A ‘desired consequence’ score is assigned for subproducts or subservices in which there are substitutes for the item and usage would not require any redesigns or significantly reduce the functionality or quality of the supply chain’s product or service.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Group</th>
<th>$\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vital</td>
<td>Not Replaceable</td>
<td>1.0</td>
</tr>
<tr>
<td>Necessary</td>
<td>Not Easily Replaced</td>
<td>0.6</td>
</tr>
<tr>
<td>Necessary</td>
<td>Easily Replaced</td>
<td>0.3</td>
</tr>
<tr>
<td>Desired</td>
<td>Easily Replaced</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Table I: Consequence Score

Development of Risk Model
In order to examine risk, a model needs to be derived to account for and accumulate all possible sources of risk in the supply chain. Risk may originate at one of the suppliers, at the firm, or at one of the customers. The formula presented in equation (5) focuses on the product(s) produced by the supply chain and the affects of a disturbance in the supply chain by the three potential origins of a disturbance (a supplier, the firm or a customer). The risk formulation derived accounts for these three sources of risk: an internal risk due to supplied subitems, an internal risk due to the firm’s processes, and an external risk due to order cancellations from the customer. For a single product, the internal portions of the supply chain’s risk are summed for a potential risk of one, and the external portion of the risk has a potential of one.

Assume there are $n$ subitems (subproducts, subservices) indexed by $i$, there are $m$ suppliers indexed by $j$, there are $p$ final products indexed by $q$, there are $r$ firms indexed by $h$, and there are $k$ customers indexed by $g$. In conjunction with the consequence score of a subitem or customer, the risk index utilizes the percentage of value added to the final product by the supplied item ($\beta_{s_{i}}$), the percentage of the final product delivered by a given firm ($\beta_{f_{q}}$), the
percentage of final product consumed by a given customer \( (\beta_c) \), and the probability of each succeeding. For the supply chain structures shown in Figure 1, the formula for calculating the risk index (RI) of a supply chain structure is,

\[
RI = \sum_{q=1}^{p} \left[ \left( \alpha_c \beta_c \right) \left( 1 - \left( 1 - \prod_{j=1}^{m} P(\bar{s}_j) \right) \right) + \alpha_f \beta_f \left( 1 - \left( 1 - \prod_{h=1}^{r} P(\bar{f}_{qh}) \right) \right) + \alpha_c \beta_c \left( 1 - \left( 1 - \prod_{g=1}^{n} P(\bar{c}_{qg}) \right) \right) \right] \tag{5}
\]

where,

\( \alpha_{qi} = \) the consequence to the supply chain should the i\textsuperscript{th} subitem for the q\textsuperscript{th} product not be supplied;

\( \beta_{qi} = \) the percentage of value added to the q\textsuperscript{th} product by the i\textsuperscript{th} subitem

\( P(\bar{s}_j) = \) the probability of the j\textsuperscript{th} supplier of the i\textsuperscript{th} subitem failing

\( \alpha_f = \) the consequence to the supply chain should the firm for the q\textsuperscript{th} product fail

\( \beta_f = \) the percentage of value added to the q\textsuperscript{th} product produced by the firm

\( P(\bar{f}_{qh}) = \) the probability that the h\textsuperscript{th} firm for the q\textsuperscript{th} product fails

\( \alpha_c = \) the consequence to the supply chain should the q\textsuperscript{th} product fail to be sold

\( \beta_c = \) the percentage of net sales for the whole supply chain represented by the q\textsuperscript{th} product

\( P(\bar{c}_{qg}) = \) the probability of the g\textsuperscript{th} customer of the q\textsuperscript{th} product failing

In the determination of the probabilities of failure for a single supplier, the following substitution must be used: if \( m=1 \), then \( 1 - \left( 1 - \prod_{j=1}^{m} P(\bar{s}_j) \right) \) becomes \( P(\bar{s}_j) \). This substitution
is also applicable to the determination of the probabilities of failure for a single firm, or a single customer. The risk index calculated by equation (5) is a relative measure of the supply chain’s vulnerability. Small values of the index suggest little or no affect from a supplier, firm, or customer failure. Larger values of the index suggest major, negative affects to the supply chain’s competitiveness due to an interruption in the product’s flow to the marketplace.

**Conclusion / Future Research**

A mathematical model has been developed in an attempt to evaluate risk within the supply chain. Through further research of this risk assessment methodology, we hope to examine several factors that affect the managerial decision-making in supply chains. We hope to examine and answer questions related to:

1. How the supply chain structure may be improved, and
2. Identifying cost effective and risk reducing methods for supplier and customer relationship improvement.
References


