IOWA STATE UNIVERSITY
Industrial and Manufacturing Systems Engineering

5th Annual IMSE Student Research Symposium
20th April, 2017

Arun Vinayak
Advisor & co-author: Dr. Cameron A. MacKenzie

Quantitative Models for Supply Chain Risk Analysis from a Firm's Perspective

Cost-Effectiveness Analysis of Supplier Performance based on SCOR Metrics

Overview of SCOR model (Supply Chain Operations References)

- Developed by the Supply Chain Council in 1996.
- Allows firms to perform very thorough fact based analysis of all aspects of their supply chain by providing a complete set of process details, performance metrics, and industry best practices.
- Identifies 5 core supply chain performance attributes with 10 level-1 metrics and 43 level-2 metrics.

5 STEP FRAMEWORK

STEP 1: Form the Objectives Hierarchy with KPIs derived from the SCOR Metrics that are relevant to the firm while evaluating a supplier.

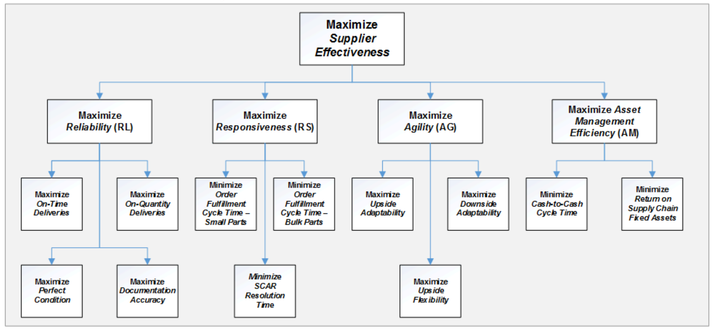
STEP 2: Develop Value functions

STEP 3: Assess trade-off weights

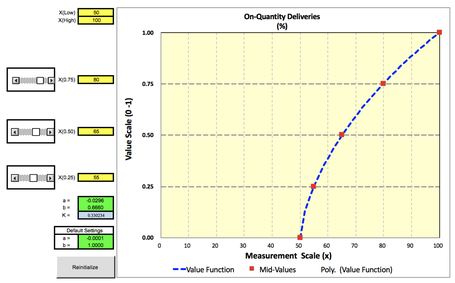
STEP 4: Develop overall measure

STEP 4: Perform Cost-Effectiveness Analysis

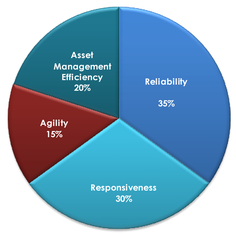
1. Objectives Hierarchy: From SCOR Metrics to Key Performance Indicators (KPIs)



2. Value Functions Assessment: Marginal Preferences in KPI values



3. Weights: Making tradeoffs between KPIs



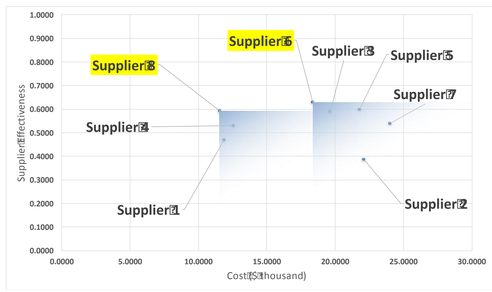
4. Overall Measure: Supplier Effectiveness

Supplier Effectiveness of j^{th} supplier,

$$v(j) = \sum_{i=1}^{M} w_i v_i(x_i(j))$$

where w_i is the global trade-off weight for KPI i, $v(.)$ is a value function for KPI i, $x_i(j)$ is the level of KPI i for alternative j, and M is the total number of KPIs

5. Cost Effectiveness Analysis

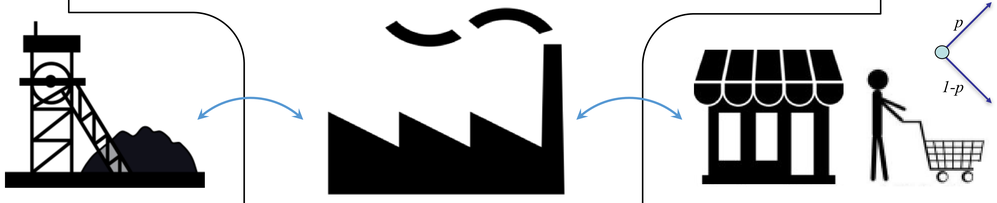


Introduction

Supply chain risk analysis garnered increased attention, both in academia and in practice, since the early 2000s. Modern production methodologies such as just-in-time and lean manufacturing, globalized supply chains, shorter product life cycle, and the emphasis on efficiency have increased the risk faced by many supply chains. Managing such risks that faces a supply chain is vital to the success of any company. Current methods employ lack consideration of market reaction and incorporation of decision maker preferences in managing supply chain risk.

1. The first study is centered on supplier side risk. It presents a framework for supplier performance measurement based on supplier KPIs derived from the performance metrics of the SCOR (Supply Chain Operations Reference) model. The framework can be used for supplier selection as well as for supplier performance monitoring as the firm continues to work with the selected supplier. Decision makers from a firm can incorporate their own preference within the presented framework to determine the most preferred supplier and assess the cost effectiveness to select a supplier in different scenarios to minimize supply side risk.

2. The second study is focused on supply chain risk from the market side in case of a major disruption. A probabilistic model based on different types of customer behaviors is developed to identify the impact on the firm's revenue by forecasting the lost revenue in case of a production shut down from a disruption event. Results from a simulation of the developed model is analyzed to draw useful insights to manage the risk of such an event.



Conclusions

1. UPSTREAM RISK
   - Identified SCOR as an effective and most comprehensive model for supplier evaluation.
   - Derived KPIs from SCOR for evaluation of suppliers from a firm's perspective.
   - Developed a framework for supplier selection based on multi-criteria decision making techniques.

   While there are hundreds of quantitative models to tackle the supplier selection problem, there is a lack of literature in supplier performance measurement aiming at supplier development using the same KPIs after the supplier selection phase. This study bridges that gap and provides managers of a firm with an easy tool that can be used to incorporate their own preferences for carefully evaluating and identifying the best supplier.

2. DOWNSTREAM RISK
   - Developed a model to quantitatively represent the way customers or the marketplace reacts to a supply chain disruption.
   - The model is used to identify the impact of such an event on the firm's revenue.
   - From the firm's perspective, the total expected lost revenue is a measure of the impact of the supply chain disruption and can be analyzed to draw useful insights to manage the risk of such an event.

   Sensitivity analysis on the model parameters reveals how the probability at which customers return to the firm impacts the recovery time. Firms that expect most of its customers to return with backorders may need to temporarily increase production capacity. Management can use the cumulative expected lost revenue projections to evaluate investments aimed at increasing the firm's resilience to supply chain disruptions.

Quantitative Model for Analyzing Market Response during Supply Chain Disruptions

Model Framework

- An unexpected disruptive event causes one or more of the firm's suppliers to default, and the firm is unable to satisfy any demand beginning at time period t = 1.
- The disruption continues for M time periods, and the firm does not deliver to its n customers for t = 1,2,..,M.
- The firm recovers from the disruption at t = M+1 and will be able to deliver at its full capacity from t = M+1.
- Each customer decides whether or not to return to the firm in each time period $t = M + i$, where $i = 1, 2, \ldots$

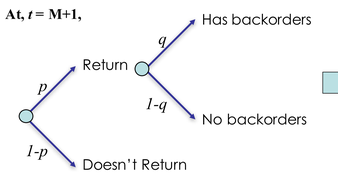
Assumptions

- Before the disruption, there are n customers (could also be retailers) who purchase from a firm in each time period before a disruption.
- Demand equals the number of customers.
- Each customer comes back to the firm with an equal probability p that remains constant in post-disruption time periods.
- Once a customer returns to the firm, we assume that it will continue to purchase from the firm in all future time periods.
- Backorders are placed only once at time $t = M+1$

Model & Insights

Types of Customer Behaviors

At, t = M+1,

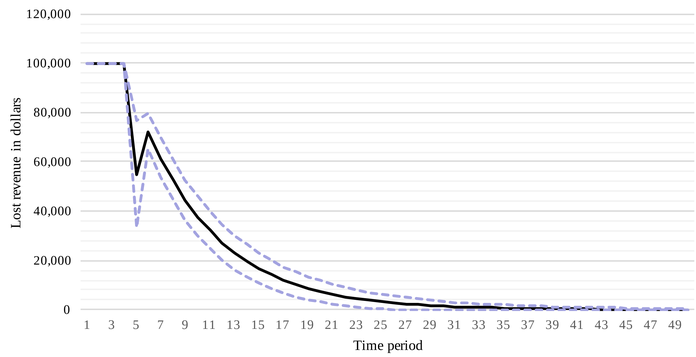


Lost revenue

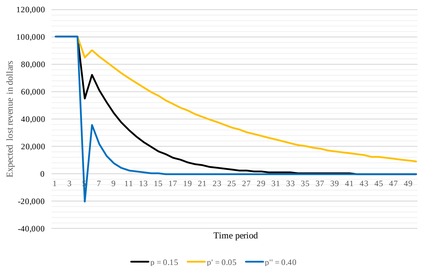
$$R_t = \begin{cases} cn & if\ t = 1,2,..,M \\ c(n - X_{M+1} - Z * M) & if\ t = M+1 \\ c\left(n - \sum_{i=1}^{t} X_{M+i}\right) & if\ t = M+2, M+3, \ldots \end{cases}$$

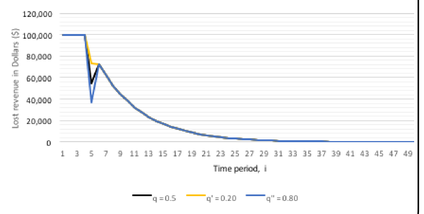
where c is the firm's per-unit selling price

The firm's expected lost revenue per period from the supply chain disruption. 90% probability interval



Risk Management Insights from Sensitivity Analysis





- Preparing to work at Overcapacity levels

Impact of p and q on:
- Expected lost revenue
- Time of recovery

Contact
Arun Vinayak - vinayak@iastate.edu