IBM Global Business Services

*White Paper*

Risk Management

# Supply Chain Risk Management: A Delicate Balancing Act

*A multi-faceted view on managing risk in a globally integrated enterprise*

Table of Contents



Risk management practices, techniques and tools have been used extensively in the financial community for years. Risks with respect to a company's supply chain have begun to receive attention only more recently, as the push to increase supply chain efficiencies has illuminated the delicate balance between financial considerations and those of the customer.

During the last twenty-odd years, supply chain management practices have evolved toward more lean process approaches in order to reduce waste within the overall chain. Concepts such as just-in- time, virtual inventory, supplier rationalization, and reductions in the number of distribution facilities have reduced total supply chain costs, but the result has been increased risk.

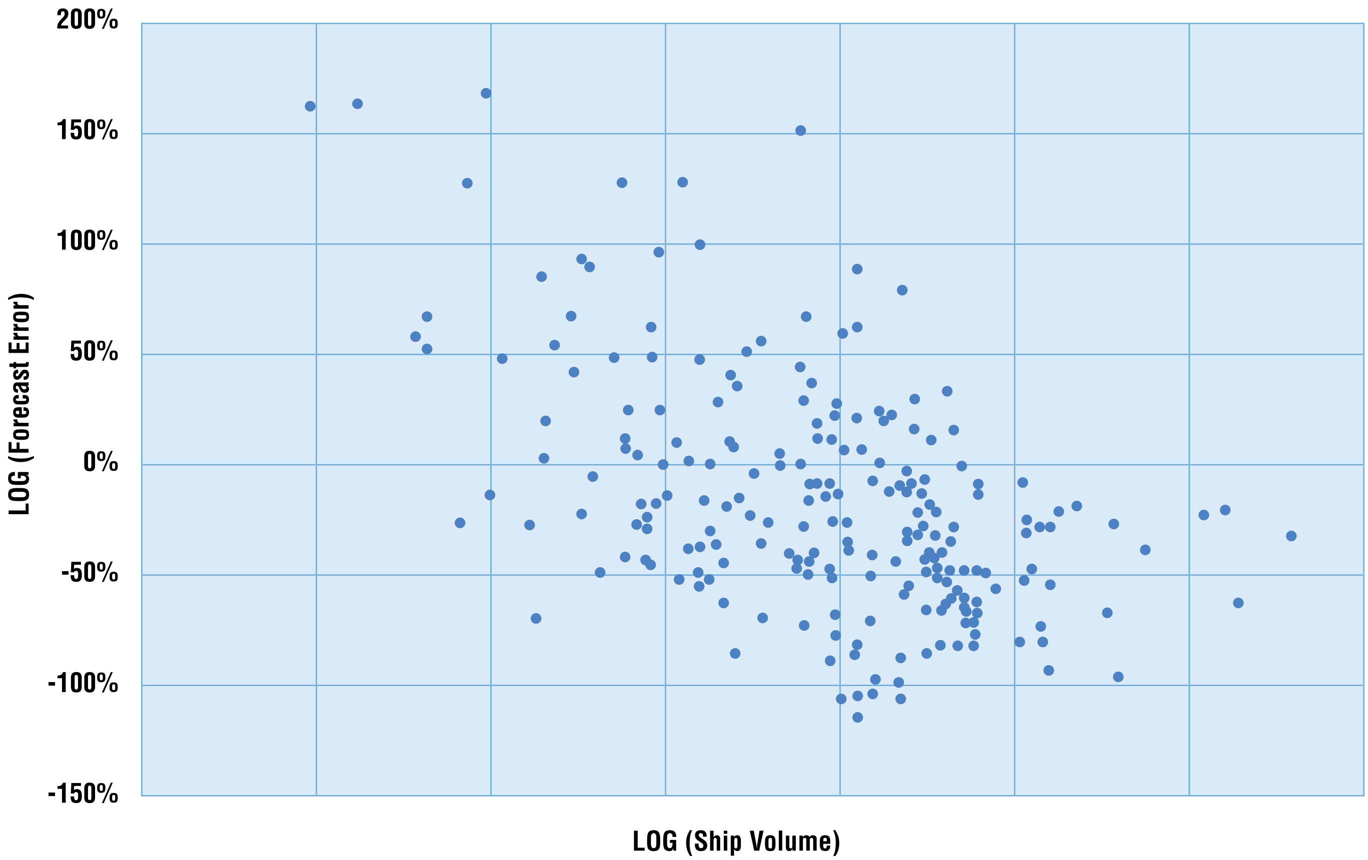
Trade-offs between achieving optimal supply chain efficiencies and management of supply chain risk have created a conundrum of sorts. Businesses have witnessed many supply chain malfunctions (with substantial consequences) due to supply and demand disruptions: the affected companies reported, on average, 14% increase in inventories, 11% increase in cost, and 7% decrease in sales in the year following the disruption. [1, 2]

Today's industrial supply chains face risks from many factors, including:

- Increased globalization through outsourcing, which elongates end-to-end supply chains
- Additional regulatory compliance imposed by government entities, further complicating international trade
- Increased levels of economic uncertainty, which create additional variability in demand and supply and make it more difficult to accomplish demand-supply balancing
- Shorter product lifecycles and rapid rates of technology change, which increase inventory obsolescence
- Demanding customers who have created additional time-to-market pressures by requiring better on-time delivery, order fill rates and overall service level efficiencies.
- Supply side capacity constraints, making it more difficult to meet demand requirements, and
- Natural disasters and external environmental events, which can wreak havoc on global supply chains.

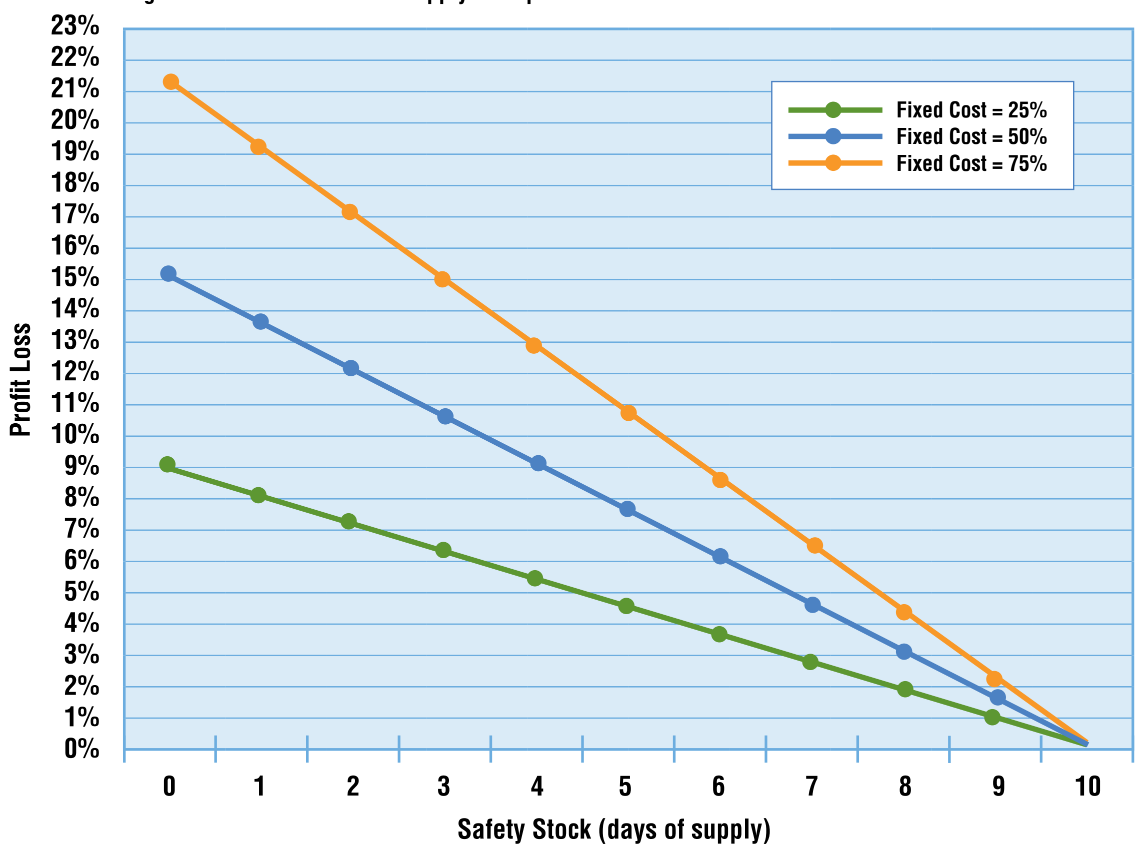
The above list includes operational and catastrophic risks because they are both important for firms to consider. From an operational perspective, complex networks of suppliers, customers and third party service providers as well as large interdependencies among multiple firms exist, making inter-organizational coordination of risks a critical requirement. In addition, the leaner and more integrated supply chains become, the more likely it is that uncertainties, dynamics and accidents in one link will affect other links in the chain.[3]

**Figure 1: Scatter Plot: Logarithmic Relationship between Forecast Error and Ship Volume (correlation coefficient = -0.59)**




Let us take a closer look at a couple of examples. As commonly known, low volume items are hard to forecast. In Figure 1 (above), we have plotted the forecast errors of 288 components that are used in computer manufacturing against their demand volume. The chart shows that there is a clear logarithmic relationship between demand volume and forecast error (indicated by a correlation coefficient of -0.59.) That is, the higher the demand volume, the lower the forecast error. Volume risk would be particularly high during product launches and phase-outs. Although during product launches inventory cost can be remedied, during the phase-outs, manufacturers face significant component obsolescence risks. The dilemma is that high customer service targets might require prohibitively high levels of safety stock during these periods.

**Figure 2: Profit Loss due to Supply Disruptions**




Next, consider a manufacturer that keeps safety stock for a product it makes. In many commodity products, profit margins are low. Suppose profit margin is 10%. The chart above shows the impact of a 10 day supply disruption on profits. Since safety stock can cover for some of the supply disruption, the higher the safety stock the lower the profit loss. For instance, if safety stock is 8 days, only 2 days of revenue is lost and hence the profit loss is for 2 days of sales only. The corresponding profit loss varies from 2% to 4% depending on how high the fixed costs are. Figure 2 (above) shows that a manufacturer with 75% fixed costs (in some manufacturing industries such as semiconductors, fixed costs can be very high) can lose more than twice as much as a manufacturer with 25% fixed costs in case they don't hold any safety stock.

Highlights

***In supply chain management, the industry has shown that survival of the unexpected is not an accident.***

**Risk and Consequence: Tales from the Industry**

There are quite a few well-known case studies illustrating situations of supply chain risk and subsequent consequences. Here, we review a sample of them – emphasizing diversity both in terms of nature (operational or catastrophic) and consequence (financial and beyond).

A well-known example of supply chain risk management is no doubt the fire that destroyed an electronics component plant in New Mexico in 2000. This plant supplied both Nokia and Eriksson. Nokia reacted promptly, securing components from the market. Eriksson, on the other hand, was left with supply shortages which translated into direct lost sales estimated at $390M. The most significant consequence of this event may have been the subsequent loss of Eriksson's market share dominance to Nokia.[4] The different reactions from similar players to a single event in time has become a key illustration point, showing the benefits of monitoring and managing risks in supply chains.

Supplier issues often lead to large and visible consequences because of their upstream position in the supply chain. In 1997, raw material and part shortages resulted in Boeing losing $2.6B. That same year, Toyota halted production for 20 days after single supplier location burned.[5]

Transportation is one of the most critical supply chain functions, and has the potential to bring just-in-time supply chains to an abrupt halt when something unexpected happens. Several events illustrate this point. In 1997, a 15-day Teamsters' strike severely affected the UPS Company, which at the time controlled 80% of all the package deliveries in the US. The strike subsequently crippled the logistics of numerous U.S. manufacturers.[6] Similarly, the September 2002 shutdown of all the West Coast ports due to the dockworkers' strike idled manufacturers and/or incurred high costs while parts were flown in.[7]

Cross-border issues, from delays due to random inspections at customs to sudden border closure such as those that followed the 9/11 attacks, lurk constantly and create vulnerability in global supply chains. There are memorable images of trucks full of parts queued up for miles at the US-Canadian border on 9/11, starving the automotive production plants (and others) of materials needed for their just-in-time assembly. While it has long been recognized that reducing inventory buffers is an excellent means of cost savings in the short run, such strategies also place risk on operations when catastrophe hits.

Supply chain visibility, or rather a lack thereof, can further compound problems. During the summer of 2007, toy maker Mattel repeatedly made the headlines for a recall of toys containing significant amounts of lead in the paint. In one specific case, the culprit seemed to be a sub-sub-contractor that decided to use paint from a non-authorized third-party supplier.[8]

Information Technology systems, while sometimes invisible, often play a central role in coordinating the supply chain. While they may attempt to enable optimal transactions among the various supply chain actors, they also introduce significant global dependencies in the supply chain operations and can have dire consequences when unreliable. For example, a glitch in Nike's demand planning software in early summer 2000 caused supply shortages for the popular Air Jordan footwear. As a result, Nike announced a $100 million sales loss.[9]

There are notable examples of successful proactive risk management where potentially major supply chain weaknesses were identified prior to an event occurring, allowing time to develop appropriate action plans to remove or mitigate the risk factor.

In the first example, a tier one automotive supplier realized that all its suppliers providing one specific component were in financial trouble. They consequently engaged designers to develop an alternative to that component. A similar example involves an aerospace and aviation company, who discovered that two independent business units (helicopters and jets) relied on the same supplier for key material. They subsequently chose to diversify suppliers. In both cases, companies reduced their risk positions significantly.[10]

While there may be many more successful examples of proactive risk management of supply chains, companies involved tend not to advertise such events, as this may place them in a vulnerable position with regards to suppliers and/or customers. However, the limited data points that we do have, point to collaborative activity with suppliers and customers as a way to reduce risk in the supply chain.

### Highlights

***Not all supply chain risks are equal.***

**Supply Chain Risk Categories**

It is often useful to consider categories of risks as a starting point to guide organizations in an initial assessment of their supply chains. Table 1 summarizes various forms of supply chain risks and vulnerabilities.

**Table 1: Supply Chain Risk Categories, with examples[11]**

| Category | Examples |
|---|---|
| Operational/ Technological | Forecast errors, component/material shortages, capacity constraints, quality problems, machine failure/downtime, software failure, imperfect yields, efficiency, process/product changes, property losses (due to theft, accidents, etc.), transportation risks (delays, damage from handling/transportation, re-routing, etc.), storage risks (incomplete customer order, insufficient holding space, etc.), budget overrun, emergence of a disruptive technology, contract terms (minimum and maximum limit on orders), communication/IT disruptions |
| Social | Labor shortages, loss of key personnel, strikes, accidents, absenteeism, human errors, organizational errors, union/labor relations, negative media coverage (reputation risk), perceived quality, coincidence of problems with holidays, fraud, sabotage, pillage, acts of terrorism, malfeasance, decreased labor productivity |
| Natural/Hazard | Fire, wild fire, severe thunderstorm, flood, monsoon, blizzard, ice storm, drought, heat wave, tornado, hurricane, typhoon, earthquake, tsunami, epidemic, famine, avalanche |
| Economy/ Competition | Interest rate fluctuation, exchange rate fluctuation, commodity price fluctuation, price and incentive wars, bankruptcy of partners, stock market collapse, global economic recession |
| Legal/Political | Liabilities, law suits, governmental incentives/restrictions, new regulations, lobbying from customer groups, instability overseas, confiscations abroad, war, tax structures, customs risks (inspection delay, missing data on documentation) |

Source: Adapted from Deleris and Erhun (2007)[11]

**Highlights**

***The starting point for managing risk is recognition of uncertain future events, likelihood of occurrence, and potential impact.***

**Disruptive Events, Uncertainty and Impact**

A straightforward approach for viewing supply chain risk management focuses on two fundamental aspects of a potentially disruptive event:

1. Probability (likelihood) of the event actually occurring
2. Impact (consequence) of the event on the supply chain, and subsequently the overall business

A first step in risk analysis is to identify potentially disruptive supply chain events. These should be customized for a particular firm. Both operational and catastrophic events should be considered, including those that involve suppliers, production, distribution and demand. As mentioned earlier, it is often useful to collaborate with suppliers and customers when possible – joint planning can help to insure that supply chain risk planning which may be costly and resulting decisions are mutually valuable to all parties.

Once all of the events that could potentially disrupt the supply chain are identified, various methods can be used to quantify their probabilities and impacts, as well as the potential impacts. The results may then be used to assess overall risk and vulnerability within the extended supply chain.

Events determined to have high likelihood and high impact, e.g. a product recall, can then be called out for further attention and analysis. The identification and classification of risky events enables supply chain managers to better understand where their supply chains are vulnerable.

One essential caveat of considering the list of hazards and their frequency and impact is that it does not capture dependency relationships between different events, both at the frequency and the impact levels. Thus, listing risks factors, assessing their probability and impact is just a first, albeit important, step toward rigorous risk management in supply chains. A holistic approach to supply chain risk management is required in order to better understand the vulnerabilities within the supply chain.

In addition, the assigned probabilities and impacts of these events can be highly subjective. This further highlights the importance of a collaborative effort, particularly for quantification of risk probabilities and impacts, with input gathered from multiple functions within and beyond the firm including marketing, finance, human resources and logistics. In fact, this exercise should be a part of the overall corporate risk management strategy.

Once risk events and their potential impacts have been identified, effective methods for managing the risks must be developed. Effective risk management requires quantifying risks to place them in their proper context and to weigh the risk costs and benefits of making particular decisions. Stochastic and simulation modeling, which embody a wide range of mathematical and numerical approaches considering random variables, offer general means to formally represent the uncertainties related to risk events. Based on these models, various forms of analysis are available to develop measures to manage and mitigate potential disruptive events that may adversely impact supply chains. In the next section, we review some of the approaches that have been suggested in the recent literature for supply chain risk management.

**Highlights**

***Math, economic and simulation models are essential to comprehensive supply chain risk analysis.***

### Models and Methods for Supply Chain Risk Management

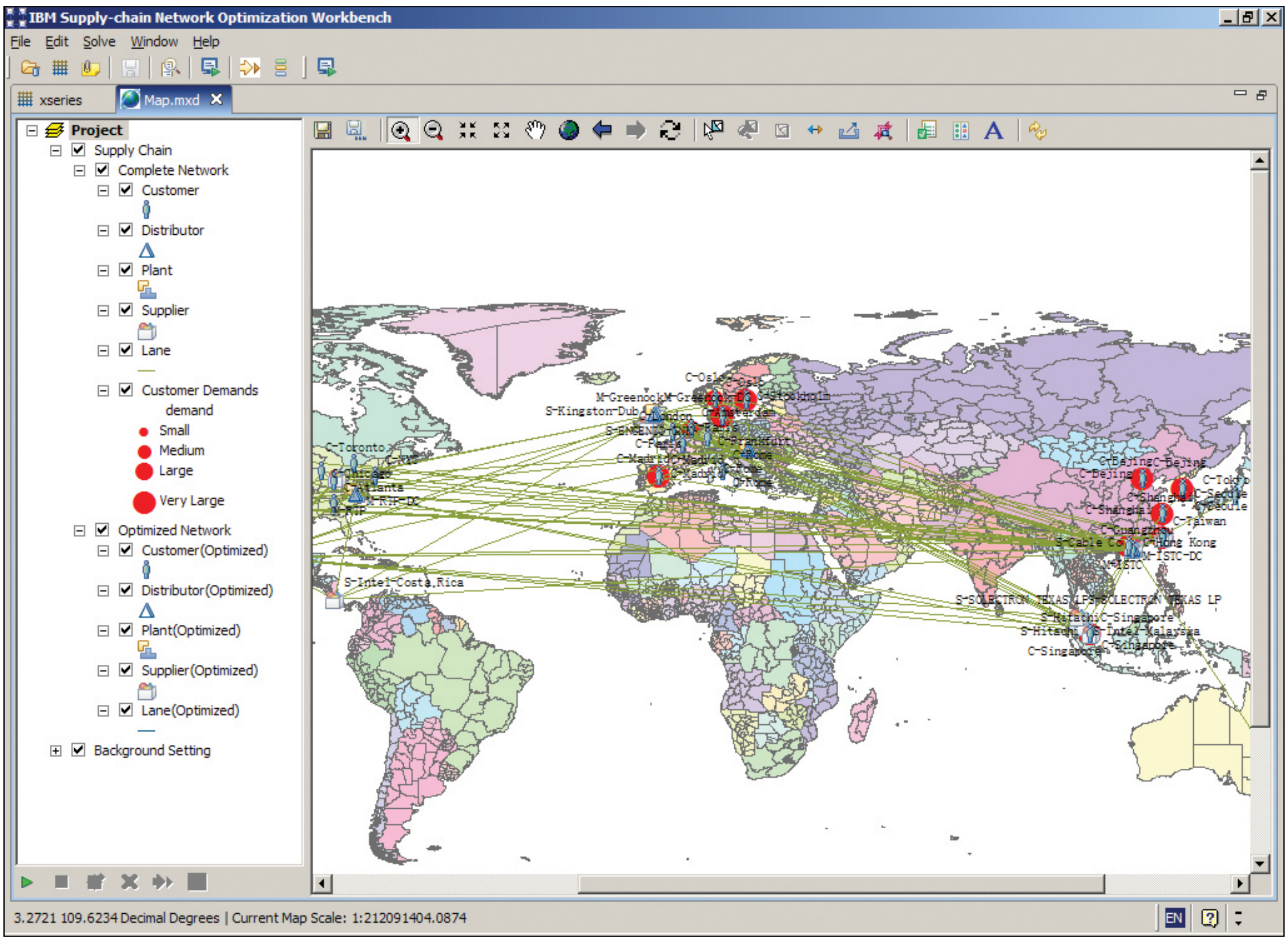
Although supply chain engineering methods have advanced rapidly in sophistication over the past two decades, the application of modeling and methods to explicitly consider and manage uncertainties and risks in supply chain activities are required for firms to advance to the next level of sophistication. The ability to identify, assess, manage, mitigate and control the impact of disruptive events within the extended supply chain sits at the heart of comprehensive supply chain risk management. For a more detailed discussion on general mathematical modeling and risk analytics, see Ray, Apte, McAuliffe and Cope (2008). [12]

Supply Chain models may be categorized into four categories:[13]

1. Deterministic analytical models, which include mathematical programming models (e.g. linear, nonlinear, integer, dynamic programming). Applications to supply chain include scheduling production, distribution planning, raw material sourcing, facility location, inventory level setting, replenishment timing and order quantity specification, and resource balancing.
2. Stochastic analytical models, where at least one of the variables involves uncertainty, and is assumed to follow a particular probability distribution. Examples of supply chain applications include inventory and production management problems, where demand and yield are represented as random variables respectively.
3. Economic models, which tend to be focused on buyer-supplier relationships. These models have a traditional base in determining the financial risks to either sellers or buyers, given various assumptions.
4. Simulation models, which are (usually) data driven representations facilitated by sampling from specified probability distributions.

All of the above modeling approaches may be useful for supply chain risk management. Typical analysis is performed by observing the impact of changes to input patterns on model output. Changes, in this case, could reflect “what if” scenarios characterizing the occurrence of a risky event. Note that the analyses are limited to the impact on the decisions for which the original model is designed to support. Of the four, simulation is the most versatile for general modeling and analysis for supply chain risk management. However, note that simulation models are usually complex to build and maintain. Note also that, to be useful in risk management, deterministic models must be embedded into a framework that simulates uncertain events.

**Figure 3: Deterministic analytical models include traditional network planning tools used for evaluating facility location, supply chain sourcing decisions and transportation policy analysis.**



Several other authors have discussed variants on supply chain modeling with the objectives of risk management. Some of the most notable include:

- Cachon (2003) discusses a few supply chain models at various levels of complexity, from the perspective of contract coordination and the risks of both supplier and receiver in the supply chain.[14]
- Datta et al (2007) propose the adaption of methods from the finance domain to risk management within supply chain.[15]
- Fisher et al (1997) use models to examine supply chain levers with the objective of improving the match between supply and uncertain demand, which represents a type of risk mitigation strategy applicable to virtually all product and service domains.[16]
- Swaminathan et al (1998) consider agent based simulation models for supply chain modeling, which enable rapid development of customized decision support tools that could certainly include risk management.[17]

No discussion of risk management modeling and methods would be complete without mention of Failure Mode and Effect Analysis (FMEA). Dating back to 1949 and use by the US Military, FMEA is a general method for identifying and analyzing potential failure modes within a system, and then for impact or severity analysis of the failures.[18] By considering risky events as "failures," it is easy to see how the methodologies can be applied directly to supply chain risk management.

FMEA is widely used among the reliability engineering community. Another thread with this community is the idea of building in system redundancy.[19] Mitigation and contingency strategies are also discussed by several current authors,[20, 21, 22] all of whom take various levels of approach with respect to modeling and analytics to make their arguments.

**Highlights**

***The server supply chain risk study illustrates an end-to-end approach for risk management.***

***Process, people and information flow are essential in the course of identifying supply chain risks.***

### Example of Risk Management for IBM's Product Supply Chain

IBM's product supply chains span multiple geographies and cover a complex network of suppliers, manufacturing sites and shippers. Recently, IBM focused on its supply chain for the System X server product. Using probabilistic risk analysis, which is based on methods originally developed to analyze complex engineering systems such as nuclear power plants and NASA space missions, the System X study provided a comprehensive and unified perspective on risk factors affecting the supply chain: from frequent operational problems to catastrophic events, and from local delays to industry-wide phenomena. Not only did the study identify risks, it also quantified the impact of loss events on the cost and order-to-delivery time for supplying the servers to its customers.

### An Approach for Identifying Supply Chain Risks

IBM used a systematic approach to identify risks to the server product's supply chain performance:

1. The study first identified risks by mapping the business processes needed in order to procure parts, and assemble and deliver machines.
2. The human, capital, and informational resources required by these processes were then mapped to indicate how they supported component activities and decisions.
3. A series of interviews with key managers and engineers identified key risk factors and root causes, which were arranged into an influence diagram indicating the cause-effect chains of failures and disruptions that impact supply chain performance. Root causes of risk included both sources of catastrophic risk as well as sources of everyday problems affecting the efficiency of the supply chain operation.
4. These influencing factors were further integrated into the business process and resource maps to pinpoint the exact location and means by which disruptions propagate into the supply chain.