GLOBAL SUPPLY CHAIN RISK MANAGEMENT

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INTRODUCTION

Individual corporations and firms have been aware of the need for contingency planning and risk management for a long time. This awareness is reflected in the abundance of literature on the topic in several disciplines, with the body of knowledge revolving around finance and insurance, economics, strategic management, and international business management. However, the firm-focused view of this knowledge offers limited applicability to supply chain management.

Due to demanding customers and competitive pressures, businesses today are restructuring themselves to operate on a global basis to take advantage of the international product, factor, and capital markets. There are several concerns in operating globally, including economic, political, logistical, competitive, cultural, and infrastructure. Typically, a firm operating internationally is part of a complex supply chain. Global supply chains require highly coordinated flows of goods, services, information, and cash within and across national boundaries (Mentzer 2001). Maximizing profits in a multi-national environment includes sourcing from locations that offer the lowest total procurement cost, manufacturing and assembling products in least cost countries, and marketing in high potential demand centers (AlHashim 1980). Many recent events (for example, SARS epidemic, and September 11 terrorist attacks, and more recently, hurricanes Rita and Katrina) demonstrate that an event affecting one supply chain entity or process may interrupt the operations of other supply chain members. Hence, it is important to look at the entire supply chain, across all countries, when selecting and implementing risk management strategies.

There is wide acknowledgement in the literature of the risks in, and vulnerabilities of, complex supply chains. Surprisingly, however, there is a lack of conceptual frameworks and empirical findings to provide clear meaning and normative guidance on the phenomenon of global supply chain risk management. For a comprehensive list of what has been published to date on supply chain risk in major logistics journals, readers are referred to a literature review by Paulsson (2004). On a positive note, a review of recent literature reveals structured and systematic approaches for assessing risks in businesses and supply chains (Harland, Brenchley, and Walker 2003; Hauser 2003). Although limited in scope and spread out across multiple disciplines, the literature is very insightful and provides excellent input to begin conceptualizing a model of global supply chain risk management.

The objective of this paper is to bring together the concepts, frameworks, and insights from several disciplines – primarily logistics, supply chain management, operations management, strategy, and international business management – to propose a comprehensive risk management and mitigation model for global supply chains. The model is intended to equip managers with a step-by-step procedure to identify, assess, and manage risks in their global supply chains, and guide future research.

CHALLENGES FACING GLOBAL SUPPLY CHAINS

Several challenges, though common in both domestic and global supply chains, are more significant and critical in global operations. It is important to study the differences between domestic and global supply chains to contrast the risks faced in each with respect to the objectives of a supply chain.

The objective of supply chains is profit maximization (Hise 1995; Nelson and Toledano 1979). Finding the balance between productivity (efficiency) and profitability (effectiveness) (Mentzer and Firman 1994) to move goods and materials between nations in a timely and seamless manner (Bowersox and Calantone 1998a) so as to enhance the profitability of the supply chain as a whole is the guiding mantra. Global supply chains must take into account differences in economies, cultures, politics, infrastructure and competitive environment (Schmidt and Wilhelm 2000). Economic challenges include such considerations as transfer prices, tax rates, duties, exchange rates, and inflation (Nelson and Toledano 1979). Infrastructural differences such as available modes; quantity, quality, and type of documentation; and the number and nature of intermediaries and facilitators (banks, warehouses, transport agencies, etc.) may require organizations to alter and/or reconsider strategies used in home countries. The infrastructural limitations in some developing economies may impose constraints on the efficiency of logistical systems (Mentzer and Samli 1981). The competitive environment, coupled with relatively high resource requirements, may create significant challenges in terms of customer service levels, anticipated costs, and desired profitability. Political factors such as stability of government, law and order, and sanctions have implications for supply chain structure and related costs. Administering and managing a global logistics system creates conflict between central management of the entire system and local management of each division of the total system (Nelson and Toledano 1979). In sum, global supply chains have potentially more delay points, greater uncertainties, and hence the need for greater coordination, communication, and monitoring.

The above challenges translate into the need for a unique set of performance measurement standards due to fluctuations in national currencies and varying inflation rates among both industrialized and developing countries, an organization structure capable of transferring knowledge and skills on a global basis, desirability of mastering a complex set of relationships (pertaining to integrating a system of domestic laws), and executive leadership with competency in managing logistical and informational flows to support global marketing and manufacturing strategies (Bowersox and Calantone 1998b; Bowersox and Sterling 1982).

At this point, it is reasonable to ask the question, if global supply chains are complex and difficult to manage, why would a firm choose to go global? The answer is that global configurations provide access to cheap labor and raw materials, subsidized financing opportunities, larger product markets, and the governments of different countries may sometimes offer widely varying inducements (e.g., tax abatements) to attract new business. Further, they may also deny sanctuaries to competitors by locking in suppliers and/or customers. Kogut (1985) identifies ways to profit from global operations: production shifting, tax minimization, financial markets, and information arbitrage. The advantages of global supply chains are outsourcing; transnational mobility of capital, information, people, products and services; increased e-business opportunities; tremendous leaps in information technology; and exploiting economies of location, such as differences in labor costs, productivity levels, and taxes (Harland, Brenchley, and Walker 2003).

CONCEPT DEFINITIONS

For the purposes of this paper, uncertainty is defined as the perceived inability to predict something accurately (Milliken 1987). A key characteristic of uncertainty is the inability to either develop a probabilistic estimate or list all possible alternative outcomes related to a decision or an event.

Several conceptualizations of risk exist in the literature. The finance literature looks at risk primarily in terms of probabilities of expected outcomes; variability of returns on a portfolio of investments; or risk of default, bankruptcy, and/or ruin (Beaver 1966). In the strategy literature, risk has been defined by using risk adjusted rates of return on capital investment (Christensen and Montgomery 1981), variability of expected and actual returns (Bettis 1981), risks of strategic actions (such as doing business with incompetent partners), and relational risks such as opportunistic behavior like cheating, distorting information, and/or partner firms stealing customers (Baird and Thomas 1985; Bettis and Mahajan 1985). Marketing looks at risk in terms of customer behavior and is primarily

concerned with the nature and importance of buying goals and failure in meeting psychological or performance goals (Cox 1967).

Management and psychology literature dealing with managerial preferences explores the link between individual disposition to risk, probabilities of outcomes, and the expected outcome values. "When dealing with a risky alternative whose possible outcomes are generally good (e.g., positive monetary outcomes), human subjects appear to be risk averse; but if they are dealing with a risky alternative whose possible outcomes are generally poor, human subjects tend to be risk-seeking" (Kahneman and Tversky 1979). Further, Tversky and Wakker (1995) argue that an event has more impact on choice when it turns an impossibility into a possibility or a possibility into a certainty than when it merely makes a possibility more or less likely. It is interesting to note that most work in psychology represents risk as a situation in which probabilities and outcomes are well-specified. This has two implications. First, in real life, accurate probability estimates may not always be available, and hence strategies need to be developed in light of flexible probabilities and outcomes. Second, the risk-seeking or risk-aversion of a single decision maker may impact risk management decisions. Hence, a team-based approach to risk management might be more suitable for making critical global supply chain decisions.

Baird and Thomas (1991) found that some risk definitions are more significant in high growth than low growth industries. For example, whereas definitions of risk based on the importance of the outcome and lack of information did not show significant differences between low and high growth industries, definitions of risk based on innovation and failure to reach targets were significantly more important in high growth than low growth industries. Pablo (1999) found that industry influences the way managers interpret risk. In sum, industry "mindsets" should be suitably accounted for in any risk management decision.

Looking at some of the more objective definitions of risk, Harland, Brenchley, and Walker (2003) define risk as a chance of danger, damage, loss, injury, or any other undesired consequences. Mitchell (1995) suggests risk contains different types of losses, and the risk of any particular type of loss is a combination of the probability of that loss, $P\ (Loss_n)$, and the significance of that loss to the individual or organization, $I\ (Loss_n)$. Therefore, for an event n:

$$Risk_n = P\ (Loss_n)\ x\ I\ (Loss_n)$$

From the discussion above, it is evident there are differences in the way disciplines address risk. However, the following three components are present in all conceptualizations of risk:

1. What are the potential losses, i.e., if the risk is realized, what losses will result?
2. How likely are those losses, i.e., the probability (likelihood) of the occurrence of an event that leads to realization of the risk?
3. What is the significance of the consequences of the losses?

The likelihood of an event occurring depends partly on the extent of exposure to risk and partly on the likelihood of a trigger that leads to the realization of the risk (Harland, Brenchley, and Walker 2003). Some powerful organizations and individuals may be in a position to partly or fully influence the realization of risk. Less powerful organizations may only be able to cope with and react to these business environment influences. It may not be possible to reasonably estimate the significance of consequences accompanying all kinds of risk. Harland, Brenchley, and Walker (2003) propose that consequences may be estimated reasonably accurately if there are regulations or laws that define compliance. Also, the significance of consequences varies with the nature of different circumstances, e.g., a local firm may get more coverage in the press than an unknown firm. To summarize, our definition of risk is the same as that of Mitchell (1995) above, but includes both quantitative and qualitative losses. For supply chain risk, for example, the quantitative losses may be lost sales due to stockouts, and the qualitative losses may be loss of brand equity or termination of a business relationship.

RISK ASSESSMENT PARADIGMS

Several tools and frameworks have been suggested in the literature as means of risk assessment. These tools and frameworks are based primarily on one of the two major paradigms for risk assessment: probabilistic choice and risk analysis (Miranda and Proenca 1998a, 1998b). Probabilistic choice (PC) is based on the concept that unwanted choice (i.e., bad situations) will be compensated with good events. Therefore, a solution can be evaluated based on its average behavior. However, there are cases where there is not enough repetition of events or situations, so probabilistic compensation of bad and good results cannot be assumed. For example, if a catastrophe occurs, no reasonable recovery is possible. In such cases, the Risk Analysis (RA) paradigm is more applicable. The RA paradigm works on the concept of minimizing regret. Regret is the difference between the cost of an optimal solution that would have been adopted if the decision maker knew beforehand what would happen, and the cost of the solution actually adopted. Since the RA paradigm evaluates regrets, the preference and risk aversion of the decision maker is taken into account in the process of selecting acceptable solutions.

The PC approach tends to favor extreme solutions, while the RA approach has a more cautious and balanced approach. In global supply chains, some risky events may not repeat themselves often enough to provide decisions based on probabilities, for example, the SARS outbreak. On the other hand, lead time variations provide enough historical data to get reasonably good estimates of expected lead times. Therefore, depending on the type of risk events, a combination of RA and PC is a reasonable approach for global supply chain risk assessment.

IDENTIFYING UNCERTAINTIES AND RISKS IN GLOBAL SUPPLY CHAINS

To manage global supply chain risk, companies need to follow a path from risk identification to strategies to deal with risks. This path is depicted in Figure 1, and guides the following discussion.

Two trends affecting the dynamics of global supply chains are the globalization and consolidation of firms, with increased uncertainty both for the firm making these changes as well as its competitors (Abrahamsson, Aldin, and Stahre 2003). Uncertainties in logistics operations exist at strategic, tactical, and operational levels (Schmidt and Wilhelm 2000). These uncertainties become further pronounced by the challenges in the global environment, such as escalating oil prices and security issues. All these factors should be taken into consideration in the design of multi-national logistics systems (Nelson and Toledano 1979). Further, incomplete information on whether some issues (e.g., concerns regarding bribery in some developing countries) are "negotiable" or "rigid" also contributes to uncertainties faced by global supply chains.

Another feature of global competition is uncertainty over competitive advantages, including the lack of historical rules regarding initial moves and competitive reactions (Kogut 1985). On a macro level, there are fundamental shifts in comparative advantages of countries. An example is the shifting of manufacturing bases to Asian countries such as China and India. On a more micro level, local firms in different countries may be radically different in their approach to, and priorities in, conducting business.

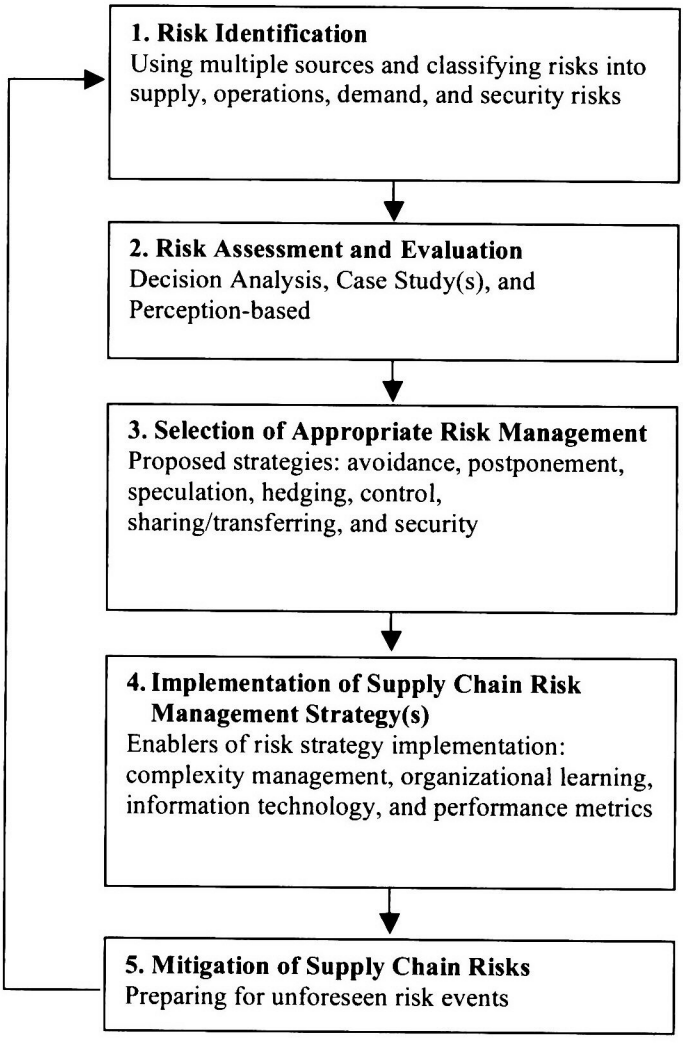
Two other factors critical to the performance of a global supply chain are uncertainty of lead times and supplier reliability (Schmidt and Wilhelm 2000). All logistics activities have the potential to be affected by lead-time uncertainty (Speh and Wagenheim 1978). Bowersox and Calantone (1998b) observe that although it is possible to eliminate some aspects of extended lead times using advanced IT, the physical transport of goods necessitates long transit times characterized by uncertainty. In sum, global supply chains are complex, constantly evolving, face multiple uncertainties, and are of importance to all levels of the organization.

Supply chain risk is a complex phenomenon that can be divided into sources and types of risk (Svensson 2000, 2002). Adapting Svensson's conceptualization of disturbances in supply chains, the sources of risk can be atomistic or holistic. Atomistic sources of risk signify that a selected and limited part of the supply chain is required in order to assess risk. The atomistic approach is suitable for low-value, non-complex, and generally available components and materials. Holistic sources of risk signify that an overall analysis of the supply chain is required in order to assess risk. For example, the holistic approach is preferable for high-value, complex, and rare or unique components or materials, since disruption of the supply of such materials would have wide-spread impacts upon supply chain

operations. It is important to understand the sources of risk to establish responsibility for management of risks. For a detailed discussion on atomistic and holistic sources of disturbances in supply chains, please refer to Svensson (2000).

FIGURE 1

A FIVE-STEP PROCESS FOR GLOBAL SUPPLY CHAIN RISK MANAGEMENT AND MITIGATION



Similarly, risks in the supply chain can be classified as quantitative or qualitative. Quantitative risks include stock-outs (lost sales), overstocking, obsolescence, customer discounts, and/or inadequate availability of components and materials in the supply chain. Qualitative risks include lack of accuracy, reliability, and precision of the components and materials in the supply chain. Both qualitative and quantitative risks may create the need for atomistic or holistic evaluations of supply chains.

To better understand the sources of qualitative and quantitative risk and to develop a categorization of risk more relevant to global supply chains, the sources of risk can be divided into supply risks, operations risk, demand risks, security risks, macroeconomic risks, policy risks, competitive risks, and resource risks (See Table 1). All have been discussed in great detail in the international business literature (Ghoshal 1987), since they affect the strategic

decision making level of the SBU. However, the first four of these risks are specifically associated with supply chains (See Figure 2) as they disrupt the operations of matching supply with demand. Most of these risks are overlapping and do not exist in isolation. Moreover, macro, policy, competitive, and resource risks manifest themselves in the form of a combination of supply, demand, operational, and security risks. For example, wage rate shifts are covered under supply, demand, and/or operational risk depending on what part of the supply chain is affected. Hence, we focus here only on supply, demand, operational, and security risks.

TABLE 1

SUMMARY OF RISKS

Type of risk	Source
Supply Risks	Disruption of supply, inventory, schedules, and technology access; price escalation; quality issues; technology uncertainty; product complexity; frequency of material design changes
Operational Risks	Breakdown of operations; inadequate manufacturing or processing capability; high levels of process variations; changes in technology; changes in operating exposure
Demand Risks	New product introductions; variations in demand (fads, seasonality, and new product introductions by competitors); chaos in the system (the Bullwhip Effect on demand distortion and amplification)
Security Risks	Information systems security; infrastructure security; freight breaches from terrorism, vandalism, crime, and sabotage
Macro Risks	Economic shifts in wage rates, interest rates, exchange rates, and prices
Policy Risks	Actions of national governments like quota restrictions or sanctions
Competitive Risks	Lack of history about competitor activities and moves
Resource Risks	Unanticipated resource requirements

FIGURE 2

RISK IN THE EXTENDED SUPPLY CHAIN

Adapted from Mentzer (2001)

Supply risk is the possibility of an event occurrence associated with inbound supply that may cause failures from supplier(s) or the supply market, such that the outcome results in the inability of the focal firm to meet customer demand within anticipated costs, or causes threats to customer life and safety (Zsidisin et al. 2004). Supply risks reside in the course of movement of materials from supplier's suppliers to the focal firm, and include reliability of suppliers, single versus dual sourcing, make or buy decisions, centralized versus decentralized sourcing, and security issues.

The risk components of supplier reliability include adverse selection (misrepresentation of a supplier's ability), moral hazard (inadequate efforts by the selected supplier), and goal conflict. The risk components of single versus multiple sourcing strategies include disruption of supply (voluntary/opportunistic or an event such as fire or

bankruptcy), disruption of inventory and/or schedules (single sourcing may lead to better dock usage but delivery problems may escalate), disruption of technology access (multiple sourcing provides broader coverage of potential sources of technological developments), price escalation (single sourcing may reduce prices due to stable schedules), and quality issues (multiple sourcing weakens the tie between customer and vendor, single sourcing may be better for quality) (Berger, Gerstenfeld, and Zeng 2004; Treleven and Schweikhart 1988). The risk components of make or buy decisions include technological uncertainty, product complexity (i.e., the number of product components, interactions to manage between these parts, and degree of product novelty) (Novak and Eppinger 2001; Walker and Weber 1987), and frequency of material design changes.

Treleven and Schweikhart (1988) suggest that backward integration is tantamount to internal single sourcing. Hence, internal sourcing may be subject to some of the risks of single sourcing. Centralized versus decentralized international sourcing includes the nature of commodities (centralize for sophisticated commodities), frequency of material design changes (decentralize for frequent material design changes), and criticality of interaction with supplier (decentralize when interaction with supplier is critical) (Narasimhan and Carter 1990).

Operations risk is the possibility of an event associated with the focal firm that may affect the firm's internal ability to produce goods and services, quality and timeliness of production, and/or the profitability of the company. Sources of operational risk reside within the firm and may result from a breakdown in core operations, inadequate manufacturing, or processing capability (Simons 1999), high levels of process variations, changes in technology that may render the current facilities obsolete, and/or changes in operating exposure. An example of change in operating exposure is exchange rates that often affect the operating profits of companies that have no foreign operations or exports but face important foreign competition in the domestic market. The structure of markets in which the company and its competitors source labor and materials and sell products determines operating exposure. Hence, operating profit may not necessarily be linked to the currency in which prices are quoted and may vary with real exchange rates (Lessard and Lightstone 1986).

Demand risk is the possibility of an event associated with outbound flows that may affect the likelihood of customers placing orders with the focal firm, and/or variance in the volume and assortment desired by the customer. Sources of demand risk reside in the movement of goods from the focal firm to the customer's customers. Sources of demand risk could be delayed/inappropriate new product introductions (leading the firm to either miss market opportunities or inventory write-offs/stock-outs due to inaccurate forecasting), variations in demand (caused by fads, seasonality, and new product introductions by competitors), and chaos in the system (caused by overreactions, unnecessary interventions, and distorted information from the downstream supply chain members) (Johnson 2001; Wilding 1998). Demand risks vary with the nature of the product, with functional products less risky than innovative products (Fisher 1997).

Information security risk is a threat from an unknown third party who may or may not be a member of the supply chain and whose motivation is to steal proprietary data or knowledge (i.e., intellectual property) and/or destroy, upset, or disable a firm's operations. The sources of information security risk include individuals within the firm leaking vital information to competitors, system hackers, and weak security/firewalls of members of the supply chain (Spekman and Davis 2004). Significant elements of infrastructure security risks are public and private utility services, for example, waterways, highways, airports, electricity and communications. Freight breaches – i.e., violation of the integrity of cargoes and products, leading to the loss or adulteration of goods (due either to theft or tampering for criminal purpose, e.g. smuggling weapons inside containers) – are a major security risk for supply chains.

RISK ASSESSMENT IN GLOBAL SUPPLY CHAINS

The risk assessment tools and frameworks for global supply chains can be divided into three broad categories: decision analysis, case study, and perception based. Since all these approaches rely to differing extents on assigning probabilities to risk events, a discussion on probability distributions of risk is in order.

Whether one uses the PC or the RA approach, it is important to understand the nature of probability distributions of risk. Sometimes the risk probability distribution follows a normal distribution. However, often the distributions are skewed left or right or are leptokurtic (flatter than normal) and have "fat tails." The consequence of

these characteristics is that extreme events happen much more frequently than indicated in calculations using normal probability distributions, and "most likely" events have a lower probability of occurrence than those calculated with such distributions. Sometimes a risk may increase exponentially with a parameter. For example, the risk of forecasting incorrectly may vary exponentially with lead times. A detailed discussion of probability distributions for both discrete and random variables may be found in Ross (2003) and Wackerly, Mendenhall, and Scheaffer (2002).

Historical data may be used to understand the behavior of risk probability distributions. However, there are many instances when there is none, inadequate, or unreliable historical data. For example, a company considering off-shoring manufacturing of some products to Asia may not have much data. In such cases, techniques such as the Delphi method may be used to assign probabilities. The Delphi method is a technique that allows people to arrive at a consensus about an issue of interest. It consists of a series of repeated interrogations of individuals who are knowledgeable on the subject. After the initial interrogation of each individual, usually by means of questionnaires, each subsequent interrogation is accompanied by information about the preceding round of replies. Each participant is thus encouraged to reconsider and, if appropriate, adjust his or her previous reply in light of the replies of other members of the group (Source: http://fwie.fw.vt.edu/rhgiles/appendices/glossd.htm and http://www.iit.edu/~it/delphi.html).

Decision Analysis

The decision analysis approach can be used to assess supply chain risks and generate a solution set. For example, Berger, Gerstenfeld, and Zeng (2004) use the decision analysis approach to determine the number of suppliers. They define decisions as having higher risk to the extent that their outcomes are more uncertain, decision goals are more difficult to achieve, and the potential outcome set includes some extreme consequences. Berger, Gerstenfeld, and Zeng (2004) suggest the use of a Critical Ratio [Critical ratio = (costs of operating with multiple suppliers – costs of operating with one supplier)/ Disaster loss] to make the single versus dual sourcing decision.

Treleven and Schweikhart (1988) present a conceptual risk/benefit assessment model for sourcing decisions, suggesting that sourcing risks can be managed by either decreasing the probability of risk components (P) or decreasing the impact for each of the risk components (I):

$$I_T = P_{ds}I_{ds} + P_{pe}I_{pe} + P_{is}I_{is} + P_{ta}I_{ta} + P_qI_q$$

Where:

I_T = the total impact of the sourcing strategy
P = probability
I = impact
ds = disruption of supply risk
pe = price escalation risk
is = inventory and scheduling risk
ta = technology access risk
q = quality risk

Case Study(s)

Harland, Brenchley, and Walker (2003) developed a supply chain network risk tool using several case studies. The tool comprises the sequence of mapping the supply network, identifying risks, and their current location, assessing risks, managing risks, and forming and implementing a collaborative supply chain network risk strategy.

Hauser (2003) suggests a business case framework to assess and manage risk in an organization. This framework allows organizations to analyze, prioritize, and measure the economic impact of risk on various business initiatives. The business case framework allows for identifying critical business issues, processes, and risks; identifying vulnerabilities; quantifying the economic impact of risks; defining a complexity/risk profile (the organization's desired risk profile); conducting simulations; identifying key performance measures; developing initiatives; and, finally, measuring performance. Such a framework provides decision-makers with financially justified value propositions for initiatives that are aligned with the company's business goals.

A critical step in the framework described above is deciding on an organization's desired risk profile, accomplished by preparing a company's inventory of risks (called the risk portfolio). A risk portfolio provides the organization with a methodology to prioritize cost and risk elements in order to achieve a best-cost outcome. "Best cost" refers to the risk adjusted cost to the supply chain. Hauser (2003) suggests using a risk map, which integrates the supply chain business-process model with a diagnostic model. Risks are listed on one axis and processes are listed on the other axis. Risks are identified and flagged using a series of predefined decision rules built into the model.

Perception Based

Simons (1999) developed a risk exposure calculator to gauge a company's likelihood of being surprised by errors or breakdowns. The risk calculator is divided into three types of internal pressures: growth, culture, and information management. Each pressure point is measured by three questions. Managers enter a number from 1 (low) to 5 (high) for each item to rate the level of pressure in their company. Although it is not a precise tool, the risk calculator does give a directional result and can determine whether the company is in a safety, caution, or danger zone with regards to its risk exposure.

Hallikas, Virolainen, and Tuominen (2002) suggest dividing the risks in supplier networks into the dimensions of severity (insignificant, minor, serious, or catastrophic) and probability (very unlikely, improbable, probable, or very probable). This tool can be useful when managers do not have hard data to build probabilistic models and have to act on available business intelligence data and intuitive understanding of the industry. For example, in the same industry, the risk of a customer finding competitive suppliers may be a serious and improbable risk for one company but an insignificant and probable risk for another, based on the volume of business and supply chain relationships.

A comprehensive framework to categorize various managerial actions that take into account risk was suggested by Norrman and Lindroth (2004). The framework is a cube with one dimension on each axis. On one axis is the unit of analysis, which moves from single logistics activities to company logistics to dyadic relations to supply chain to supply network. On the second axis is the risk and business continuity management process, which goes from risk analysis at the lowest level to business continuity management at the highest. Risk assessment and risk management are placed in between. On the third axis is the type of risk and uncertainty and progresses from operational accidents to operational catastrophe to strategic uncertainties.

At the heart of risk assessment is asking the right questions. Bookstaber (1997) asserts that the analytical structure that is often at the center of global risk management tends to focus resources on refining the available answers, and on answering them with even more detail and sophistication. Therefore, the organization should encourage asking the right questions of knowledgeable managers. Extending this logic into the context of global supply chain risk, the manager should continually look at the critical interface points in the supply chain to assess different potential risks.

RISK MANAGEMENT STRATEGIES AND MITIGATION PLANS

At the strategic level, risk management is focused on identifying and assessing the probabilities and consequences of risks, and selecting appropriate risk strategies to reduce the probability of, or losses associated with, adverse events. Risk mitigation focuses on reducing the consequences if an adverse event is realized (Norrman and Jansson 2004).

Amit and Wernerfelt (1990) suggest three motives for businesses to manage risk. First, the agency motive argues that relatively low risk firms have low firm-value. Managers consider both market and business risk, but shareholders care only about market risk since they can diversify their portfolios to account for business risk. Second, the cash flow motive suggests that higher cash flows are associated with lower business risk. In a stable environment, corporate operations are efficient and earnings volatility is low. Third, the rate of return motive asserts that a positive relationship exists between rate of return and business risk. However, due to transaction costs such as brokerage fees and time costs, shareholders are willing to accept stocks with lower risks.

Risk management strategies can be classified primarily into seven categories: avoidance, postponement, speculation, hedging, control, sharing/transferring, and security (Jüttner, Peck, and Christopher 2003; Miller 1992), though the different strategies are closely related to each other. Further, the use of one strategy may mandate the use of another strategy (e.g., a hedging strategy entails avoiding some risks).

Avoidance

Avoidance strategy is used when the risks associated with operating in a given product or geographical market, or working with particular suppliers or customers, is considered unacceptable. In avoiding risks, managers are aware of the supply-demand and/or operating trade-offs associated with the options and choose to avoid some risks. Avoidance may take the form of exiting through divestment of specialized assets, delay of entry, or participating only in low uncertainty markets (Miller 1992).

Postponement

Postponement entails delaying the actual commitment of resources to maintain flexibility and delay the incurring of costs (Bucklin 1965). Perry (1991) argues that, based on the uncertainty projected in the operating environment, postponement has significant potential benefits. Form postponement includes labeling, packaging, assembly, and manufacturing. Time postponement refers to the movement of goods from the manufacturing plants only after customer orders are received (Zinn and Bowersox 1988). The extent of postponement depends on demand customization, component costs, product life cycle, and product modularity (Chiou, Wu, and Hsu 2002).

Speculation

Speculation (also called assumption or selective risk taking) is the opposite of postponement (Bucklin 1965). In speculation, decisions are made on anticipated customer demand. When customer-service standards are defined by the competitive environment and customer-driven, supply chain resources are directed to those specific products and customers that provide the firm with a competitive advantage (Perry 1991).

Hedging

The statistical approach and the economic approach are two ways to hedge risks (Chichilnisky and Heal 1998). The statistical approach (insurance) is based on the law of large numbers. With a large enough population, the number likely to be affected is known with considerable accuracy. The sample mean is highly predictable if the distribution for each person or group is known. The economic approach works when the same event may occur for many people all at once. For example, a drop in U.S. dollar value is the same for everyone in the U.S. economy. The ideal hedge is to combine the above two approaches to achieve a position such that no financial catastrophe exposes the insurer to risks higher than can be afforded.

In a supply-chain context, hedging is undertaken through a globally dispersed portfolio of suppliers, customers, and facilities such that a single event (like currency fluctuations or a natural disaster) does not affect all the entities at the same time and/or with the same magnitude. For example, dual sourcing can be used as a hedge against risks of quality, quantity, disruption, price, and opportunism. Similarly, while the underlying cost structures in plant and technology acquisition and operating costs are specific to the industry, production risks can be offset by operating faster, more flexible plants, versus dedicated, efficient plants. Multiple contracting acts as a hedge to reduce variability in performance and a shield against single supplier opportunism.

Control

Some of the risks that provide incentive for vertical integration are opportunism and asset specificity by the supplier, capacity constraints, and the supplier-buyer power balance (Achrol, Reve, and Stern 1983; Ellram and Siferd 1998; Williamson 1979). Vertical integration may increase control by reducing the risks of supply or demand failures in the supply chain, but it changes variable costs into fixed costs. Hence, there is a strong incentive for an organization to satisfy high probability demand itself and pass on low probability demand to other firms (Carlton 1979). This is called partial or tapered integration, which leads to full utilization of the equipment of the firm and allows the supplier to absorb the risks. Designing flexible contracts with clauses that account for possible changes in

the environment and associated risks also acts as a control mechanism (Macneil 1978). Contracts with suppliers based in the host country but having manufacturing facilities in low-cost countries provide the benefit of low-cost and better access to legal recourse if things go wrong.

Transferring/Sharing Risk

The transfer and/or sharing of risks in a supply chain can be achieved through outsourcing, off-shoring, and contracting. Global supply chain outsourcing can take the form of domestic or international sourcing of services and products. In global supply chains, the term "off-shoring" more effectively conveys the idea of sourcing across borders. Outsourcing/off-shoring entails a transfer of risk to suppliers, but the collective risk of off-shoring should be assessed against control.

International factoring, a form of off-shoring treasury services, is used mainly by exporters to take care of cash-flow concerns and concentrate on core activities like design, manufacturing, and sales. Factors helps exporters offer favorable buying terms by providing services such as collection and credit protection (Kaplan 1996). Hence, exporters do not need to use expensive financial instruments such as letters of credit and are protected against payment delays and foreign exchange risks.

A portfolio of contracts can be used in supply chains to induce retailers with different levels of risk aversion to select unique contracts. This induces the retailers in the supply chain to order quantities that maximize the expected value. Since there are a variety of contracts from which to choose, contracting can be used to counter the inefficiencies created by retailer risk aversion (Agrawal and Seshadri 2000; Cachon 2004). A manufacturer may offer discounted advance purchase contracts for quantities ordered in advance of the selling season and a regular priced contract for replenishment during the selling season. Depending of the level of risk-aversion, different retailers may choose quantities for the two prices. Assuming a normal distribution of risk-aversion, the risk is transferred from the manufacturer to multiple retailers.

Security

Current technological research in the fields of sensors capable of identifying nuclear, chemical, and/or biological elements may help in identification of at-risk shipments. The ability to sort out what is moving, identify unusual or suspicious elements and concentrate on them, and deal with the rest of the movements through a sampling-based process may be a viable strategy. Efforts such as the Container Security Initiative, the Customs Trade Partnership Against Terrorism (CTPAT), and the overarching Operation Safe Commerce initiative provide directions that in the long term will enhance the security of global commerce (Downey 2004).

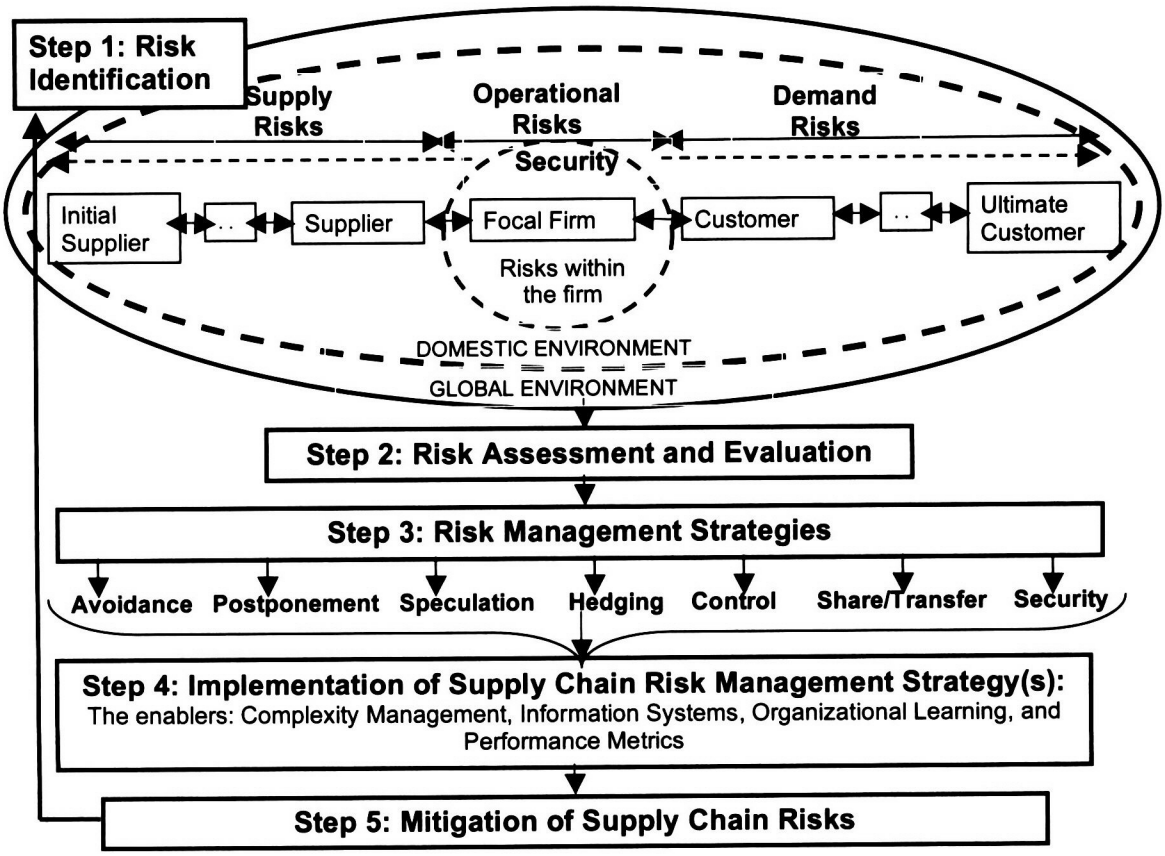
A GLOBAL SUPPLY CHAIN RISK MANAGEMENT & MITIGATION MODEL

Based on the review of the literature, a model for risk management and mitigation, comprising the five broad steps presented in Figure 1, is proposed (Figure 3):

Step 1: Risk Identification
Step 2: Risk Assessment and Evaluation
Step 3: Selection of Appropriate Risk Management Strategies
Step 4: Implementation of Supply Chain Risk Management Strategy(s)
Step 5: Mitigation of Supply Chain Risks

FIGURE 3

GLOBAL SUPPLY CHAIN RISK MANAGEMENT AND MITIGATION FRAMEWORK



Step 1: Risk Identification

Risk identification is undertaken at both domestic and global levels and in the context of supply, operational, demand, security, macro, policy, competitive, and resource risks. The global environment includes various supply chain partners, and how the environments in these different countries interact with the focal firm home country.

In this first step of the risk management framework, the objective is to create what can be referred to as a "profile" for each of the risks identified in Table 1. The risk profile contains elements of the specific risk within the broad category, whether the risk is atomistic or holistic, quantitative and/or qualitative, and affects domestic and/or global operations (See Table 2). Risks from Table 1 are entered in Column (1) of Table 2. Columns (2) through (5) are the elements of the risk profile and can be filled in based on the earlier discussions in this paper.

TABLE 2

CREATING RISK PROFILES

Broad Risk Category (1)	Description(s) of Specific Risk(s) (2)	Atomistic/ Holistic (3)	Quantitative/ Qualitative (4)	Domestic/ Global/Both (5)
Supply Risks				
Operational Risks				
Demand Risks				
Security Risks				
Macro Risks				
Policy Risks				
Competitive Risks				
Resource Risks				

Step 2: Risk Assessment and Evaluation

Not all risks affect all supply chains. A supply chain can be vulnerable to certain risks, but shielded from other risks. Hence, the next step is to determine which risks identified in Step 1 (Table 2) are critical for the supply chain. Those risks to which a supply chain is more vulnerable should be given more attention. Table 3 synthesizes the elements of the Risk Analysis and Probabilistic Choice paradigms and combines them with the risk map approach of Hauser (2003) discussed earlier to suggest a risk assessment and evaluation tool.

TABLE 3

RISK ASSESSMENT AND EVALUATION

List of Risks	Potential losses	Probability			Impact/ Consequences		Worst possible scenario	Is the worst possible scenario acceptable	Other considerations/ factors esp. competitors' exposure to similar risks	Final evaluation of risk [c]
	Quant ($)	Qual	Quant (p)[a]	Qual[b]	Quant	Qual		Yes / No		
Example of Supply Risks: Reliability of suppliers										
Disruption of supply	$10,000/ per day		0.25		$2,500 per day		Loss of 10% customers if supply disruption lasts over 3 weeks	No	Many competitors with no quality differences who can supply to our customers	Serious
Macro										
Policy										
Competitive										
Resource										

[a] $0 \leq p \leq 1$ (0 means no risk at all and 1 means a definite event)
[b] Qualitative probability: very unlikely, improbable, probable, and very probable
[c] Final evaluation of risk: Insignificant, Minor, Serious, and Catastrophic
Note: All numbers are examples only.

Step 3: Risk Management Strategy Selection

After assessing and evaluating the risks, the next step is to select appropriate strategies to manage the risk. Risk management strategies are geared toward reducing the probabilities of losses associated with risk events. The assessment of risk in Step 2 provides the list of critical risks for which risk management strategies need to be devised. Risk management strategies should be in sync with the supply chain strategy, which in turn should fit with the SBU or corporate strategy. Based on supply and demand uncertainties, Lee (2002) suggests four types (quadrants) of supply chains: efficient (high cost efficiency based on low demand and supply uncertainty), responsive (responsive and flexible to high demand uncertainty and low supply uncertainty), risk-hedging (pooling and sharing of resources in a supply chain with low demand uncertainty and high supply uncertainty), and agile (both hedging and responsive to high demand and supply uncertainty). Table 4 proposes risk management strategies depending on the quadrant in which the supply chain lies.

Table 5 is similar to the risk portfolio approach of Hauser (2003). Column (1) specifies the type of supply chain from Table 4. Column (2) pulls the most critical risks from Table 3. As discussed earlier, industry frameworks can either provide valuable inputs or impose undue constraints on identifying, evaluating, and managing risks. In either case, it is important to recognize the presence of these "mindsets" (Pablo 1999). Such an explicit consideration of industry practices provides insights into a firm's own decision making process by forcing firms to think outside current industry practices, and/or consider some options that are less "industry-experience" oriented and may otherwise be missed.

TABLE 4

SUPPLY CHAIN TYPES AND RISK MANAGEMENT STRATEGIES

		Demand Uncertainty	
		Low	**High**
Supply Uncertainty	**Low**	**Efficient Supply Chain** *Focus on Cost-efficiency* Postponement Single Sourcing	**Responsive Supply Chain** *Focus on Responsiveness and Flexibility* Postponement
	High	**Risk Hedging Supply Chain** *Focus on Pooling and Sharing Risks* Multiple Sourcing Transferring/Sharing Risk Hedging	**Agile Supply Chain** *Focus on Responsiveness and Hedging Risks* Hedging

TABLE 5

SELECTING APPROPRIATE RISK MANAGEMENT STRATEGIES (SERIOUS AND CATASTROPHIC RISKS)

Type of Supply Chain (1)	**Major Risks (2)**	**Industry Risk Management Practices (3)**	**Selected Risk Management Strategies (4)**
	From Table 3		
Efficient/ Responsive/ Risk Hedging/ Agile			

Table 6 is similar to Table 5 except that it assesses relatively minor and inconsequential risks. Some minor risks may be covered in taking care of major risks. For the remaining risks, a company may choose to leave them unattended or fix them at a more operational, rather than strategic, level. Table 6 ensures the awareness of relatively less consequential risks. It should be stressed here that strategies do not work in isolation. The selected strategies should form a coherent set that is in sync with the global supply chain strategy.

TABLE 6

SELECTING APPROPRIATE RISK MANAGEMENT STRATEGIES (MINOR AND INSIGNIFICANT RISKS)

Type of Supply Chain (1)	**Minor Risks (2)**	**Already taken care of by Table 5 strategies? (3)**	**If no, then tactical and operational measures (4)**
	From Table 3		
Efficient/ Responsive/ Risk Hedging/ Agile			

Step 4: Implementation of Supply Chain Risk Management Strategy(s)

Implementation of strategies for risk management requires certain structural, and/or procedural changes in harmony with the trends of globalization and increasingly customized product offerings. Strategy implementation requires discipline, commitment, creativity, leadership, and superior execution skills (Freedman 2003).

Freedman (2003) identifies reducing complexity as one of the key activities in strategy implementation. In global supply chains, with customers and suppliers spread across the world, firms are constantly expanding, consolidating and/or experimenting with different configurations of upstream and downstream supply chain members. An increasing number of firms are offering a customized and/or wide-ranging variety of products to customers spread out in different geographical locations. These trends, coupled with the dynamic international political, legal, and economic environments, give rise to complexity in global supply chains.

Complexity can be explained by systems theory, where the basic premise is that systems are made up of parts and a linear change in any part may cause non-linear changes in other system parts (Dubois, Hultén, and Pedersen 2004). Complex adaptive systems (CAS) suggests that systems are characterized by dimensionality (emergence/control), connectivity, self-organization, dynamism, non-linear changes (Choi, Dooley, and Rungtusanatham 2001; Wilding 1998). Global supply chain complexity affects such outcomes as delivery performance, lead times, and production lot sizes (Vachon and Klassen 2002), and leads to suboptimal interaction between such global supply chain system elements as ownership, chaos (e.g., the Bullwhip Effect), and inertia (Wilding 1998). Thus, managing complexity is critical to successful implementation of risk management strategies.

One way of managing complexity in supply chains is to make them more flexible. Upton (1994) defines flexibility as "the ability to change or react with little penalty in time, effort, cost or performance." Further, in dynamic markets, the value of a firm's strategy (e.g., speculation strategy) may increase if it can devise ways to exercise its options faster than its competitors. Flexibility must be a key component of any global supply chain system to achieve time objectives (Hise 1995). Flexibility is important in a global supply chain because it plays a facilitating role in the coordination process and provides a unique ability to help firms manage the high levels of environmental and operating uncertainty inherent in international operations. Firms that achieve higher levels of flexibility significantly outperform their less flexible counterparts (Fawcett, Calantone, and Sheldon 1996). Flexibility positively impacts not only the firm's ability to extend its global reach but also its ability to enhance comparative performance relative to leading industry competitors. Kogut and Kulatilaka (1994) argue that flexibility is an option that is valuable because of uncertainty, time dependence, and discretion. For example, a company may

choose to exploit exchange rate volatility by configuring its business to have flexibility to increase production and sourcing in countries where currencies are undervalued in real terms. This adds to the costs of switching locations and building excess capacity, but reduces average operating costs across a spectrum of exchange rates (Lessard and Lightstone 1986). In sum, supply chain flexibility provides an inherent capacity to respond to emerging and unexpected circumstances that cannot be fully anticipated in the planning cycle (Welch and Welch 1996).

Other important factors affecting strategy implementation are organizational learning, information systems, and performance metrics. The first two will be address here and performance metrics will be addressed later in this paper. Organizational learning facilitates risk identification and assessment. Organizational learning – promoting an ongoing stream of dialogue and inquiry, analyzing mistakes, seeking feedback, communicating, and questioning – affects customer service levels (Ellinger, Ellinger and Keller 2002). Bowersox and Sterling (1982) contend that corporate organizational structure must have the capability to transfer knowledge and the skills required to succeed on a global basis to all national operations. Hult, Ketchen, and Nichols (2003) found a strong link between learning and cycle time reduction. With long lead times in global supply chains, this result is significant.

Information technology is critical to the implementation of all risk management strategies and for effective management of supply chains and performance measurement (Bowersox and Daugherty 1995; Edwards, Peters, and Sharman 2001). The process of risk management – from identifying risks, through selecting appropriate risk management strategies, and making necessary structural changes in the supply chain – is an information-intensive process. The challenge is the ability to filter data for the most important information.

Step 5: Mitigation of Supply Chain Risks

Even after devising risk management strategies, all risks cannot be avoided. It is important to plan for situations that assume a risk that could be seriously detrimental may be realized. While risk management strategies are used to proactively address the probability of expected (though uncertain) events, risk mitigation planning provides a firm with a more mature decision making process in facing potential unexpected losses caused by unexpected events.

The key to risk mitigation is identifying the possible losses that may happen from an unexpected event. For example, if delivery issues are critical to a business, a risk mitigation plan should include identifying a back-up service provider, and developing a relationship with that provider to replace and/or pick up the capacity slack caused by the unexpected event. Another example may be for a company sourcing from overseas and using only water transportation to plan for usage of air freight in the event there are some disturbances in the low-cost surface options. A risk mitigation plan in this case may consist of identification of air freight service providers that can handle the specific product requirements on short notice. An approach used by some firms is to speculate on losses using a war-gaming approach. Different scenarios are discussed and reactions for the most damaging scenarios are planned.

Feedback on Strategies

Notice in both Figures 1 and 3 that a feedback arrow exists from Step 5 to Step 1. Performance metrics and reward systems affect several aspects of the risk management process, particularly the inclination of managers to look at risks proactively and continually assess their effectiveness. If the incentive system is such that it rewards only those who achieve the objectives irrespective of the risks, then managers will focus only on the objectives. If, however, managers are rewarded for considering all five Steps in the Risk Management Framework, and assessing the effectiveness of various risk management and mitigation strategies on firm and supply chain performance, then global supply chain risk management will continue to improve for the firm.

MANAGERIAL IMPLICATIONS

The intent of this paper was to provide a five-step process through which global supply chain managers can regularly identify, assess, and plan for risk. It should be recognized that all steps of this decision-making process are interactive and interdependent. Although the process appears linear and hierarchical, there should be a constant flow of information between the different steps. Supply chain decisions influence other members of the supply chain through direct and indirect effects (Novack, Rinehart, and Wells 1992). The decisions related to risk management

should reflect the consideration of other strategies and processes across the global supply chain. The effects of global supply chain risk decisions may be classified into horizontal, vertical, and diagonal effects. For example, if a firm undertakes a hedging strategy to guard against risks due to disruptions in supply, it will choose multiple suppliers for critical components (a horizontal effect of more suppliers). This will affect decisions like inventory requirements in the system, and differences in the nature of contracts between the firm and the multiple suppliers (as opposed to a single-source contract). If a firm chooses to adopt a postponement strategy, say labeling and assembly at distribution centers close to customers, it will modify the expectations from suppliers as well as affect the way in which downstream supply chain members align their systems to the postponement strategy (a vertical effect). An example of a diagonal risk management strategy would be if a firm may chose to opt out of a certain product line. This has far-reaching consequences at multiple levels and in multiple functions. It may affect, among other areas, new capacity and materials handling requirements, the set of suppliers, inventory and transportations requirements, and the number of downstream partners.

This framework for global supply chain risk management provides three main benefits. First, it offers an integrated framework for managing global supply chain risk decisions with the aid of linked tables. This step-by-step approach forces the decisions to move out of typical intuitive thinking and preset mental models. Backed by the literature, it provides an understanding of the constituents of risk, creates a risk profile, and uses the risk profile to generate a set of appropriate strategies in the context of global supply chain and SBU/corporate strategies.

Second, the model uses a mix of multiple risk assessment tools that consider both the qualitative and quantitative dimensions of risk. Moreover, it combines the benefits of Probabilistic Choice and Risk Analysis to offer a holistic method for evaluating risks.

Finally, the framework explicitly recognizes the presence of the dynamic environments in which global supply chains operate. Hence, as environments and organizations change, this framework can be used as a guideline to continually profile and evaluate risks and either fine-tune the adopted set of strategies or explore new ones.

To be used effectively by managers, the proposed tables serve as a guide and may be suitably modified to include or exclude certain elements. As discussed earlier, a team-based approach to evaluating and managing risks associated with global supply chains is useful. A cross-functional team leverages the synergy and creativity inherent in a diverse group. Outside consultants and/or experts, and peers in other non-competing industries, may also facilitate the risk assessment process.

Apart from analyzing risks at the event level, an efficient way to assess and evaluate risks may be by ordering them according to a project or a process. For instance, in ordering risks according to a project, risks may be identified and managed as threats to the project's success. For events that may have escaped identification, it is important to plan for the unexpected. In such cases, war-gaming approaches may identify several losses that may happen irrespective of the event that causes them and mitigation plans may be developed around those losses. Due to the nature of global supply chains, global supply chain risk managers should continually look at the critical interface points in the supply chain as opposed to only within firms.

RESEARCH IMPLICATIONS

Probabilities and consequences of risks need to be estimated with reasonable accuracy to gain maximum benefits from the framework. Hence, future research should develop tools and techniques to assign probabilities to events. As the discussion on complexity indicates, there is reason to suspect that global supply chains will become increasingly complex. More complexity with newer risks creates a need for innovative ways to manage complexity as a means of managing risks in global supply chains. Hence, we need to further examine the phenomenon of complexity and how it affects risk in supply chains.

Flexibility, organizational learning, information systems, and performance metrics/rewards are recognized as key enablers in the process of risk management and mitigation. We need to better understand how these enablers influence the process of risk management and mitigation, and how they can be utilized most effectively in making sound global supply chain risk management decisions.

With more qualitative and quantitative research, it is possible to validate the model presented in this paper, and generate a set of generalizations based on variables like organizational and industry characteristics. Such research will also enhance our understanding of the steps that are most critical and the steps that are most often missed and/or overlooked by global supply chain managers. Concepts and frameworks from other disciplines such as finance, investment, and insurance may also be explored to validate and/or refute parts of the model.

Finally, and most importantly, future research needs to address the issue of how this model links up with supply chain performance. There are several difficulties in inferring the contributions of risk management strategies because it is difficult to pinpoint the direct effects of strategies on supply chain performance. Some direction for designing performance measures is available in the existing body of knowledge. For example, Mentzer and Firman (1994, p. 222) suggest, "...performance measures used within a control system must be realistic, representative, consistent, cost effective, understandable, and not underdetermined." Hence, future research should attempt to develop a causal model that tests the proposition that managing and mitigating risks in the supply chain positively affects the performance of the supply chain. Further, research should answer the questions of how risk management affects performance of global supply chains and what are the moderating and mediating variables. Without such future research, managers operating in global supply chains will be overwhelmed by the complexity and magnitude of the risks involved.

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