Supply chain risk management – II:

A review of individual and integrated operational and financial approaches

Dia Bandaly[*], Latha Shanker[*], Yasemin Kahyaoglu[**] and Ahmet Satir[*]

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Concordia University

John Molson School of Business

Montreal, Quebec, Canada

**

McGill University

Center for Continuing Education

Montreal, Quebec, Canada

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Abstract

This article is a sequel to Bandaly et al. (2011). Structured around the supply chain risk management (SCRM) typology and framework presented in the aforementioned article, this article provides a review on individual operational and financial risk management approaches reported in the literature. Avoidance, prevention and mitigation approaches reported are also summarized in tabular format for the four risk domains covered (internal operations, external stakeholders, marketplace and environment). Distinctions between operational and financial approaches are highlighted. A review of studies integrating both approaches is then presented. Areas for future research in SCRM are argued.

keywords: supply chain risk management, operational, financial, integrated approaches

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1. Introduction

This review classifies and analyses operational, financial and integrated approaches used when dealing with supply chain risks. The review is structured around the supply chain risk management (SCRM) framework and typology presented in Bandaly et al. (2011). The framework identifies four risk domains: internal operations, external stakeholders, marketplace and environment. The typology classifies risk management methods into avoidance, prevention and mitigation approaches. The primary focus of the review is on multinational manufacturing companies, although the risk management approaches of non-manufacturing firms, such as service providers, retailers and distributors, are also addressed.

Section 2 reviews 'operational' risk management approaches with a focus on interaction between the firm and its supply chain partners. Section 3 reviews 'financial' risk management approaches, where the focus is on the use of financial derivatives. The section examines the key pertinent issues in integrating these instruments with operational approaches. Section 4 highlights the distinctions between operational and financial approaches. 'Integrated' operational and financial approaches are reviewed in Section 5. Section 6 presents major gaps in research in the extant literature and proposes areas for future research.

2. Operational risk management approaches

2.1. Internal operations

For the risk domain 'internal operations', three sources of risk are identified: process uncertainty, information system failures and labor uncertainty. The literature on operational approaches used when managing these risks are reviewed in the following sub-sections. A summary is provided in Table 1.

2.1.1. Avoidance approaches

Cucchiella and Gastaldi (2006) address risks such as insufficient production capacity or delays in receiving critical information and examine 'real options' risk avoidance strategies such as, deferring investment, outsourcing, scaling down and abandoning current operations.

2.1.2. Prevention approaches

Turnbull (2007) suggests adoption of quality control processes with supportive information systems to detect defective products before shipment to the end user to protect against the risk of product contamination. Use of 'P-Trans-net' model is proposed in Blackhurst and O'Grady (2004) to identify those nodes along the supply chain that contribute to the longest lead times and delays. Using 'real options' as prevention strategies are argued in Cucchiella and Gastaldi (2006). These include: i) 'stage' option, which provides the ability to abandon a project in midstream in light of new information unfavorable to continuing the project, ii) 'lease option' which provides the ability to lease an asset with an option to buy it at a later time, and iii) 'growth option' such as spending on research and development, leasing undeveloped land and strategic acquisitions, which could lead to future growth through access to new markets or strengthening core capabilities.

2.1.3. Mitigation approaches

Sheffi and Rice (2005) argue that 'conversion flexibility', which involves the use of standard processes across facilities with built-in interoperability, allows a firm to operate in another facility when one is disrupted or to replace sick or otherwise unavailable operators. According to Tang and Tomlin (2008) and Thun and Hoenig (2009), a 'flexible process strategy' allows the firm to produce multiple products efficiently and to compete on product variety and cost.

(Insert Table 1 here)

2.2. External stakeholders

The sources of risk are identified for the risk domain 'external stakeholders' are: supplier reliability, distribution and network. The literature on operational approaches used when managing these risks are reviewed in the following sub-sections and summarized in Table 2.

2.2.1. Avoidance approaches

The 'real options' cited by Cucchiella and Gastaldi (2006) and described in Section 2.1.1 could be used to avoid supplier quality and reliability issues.

2.2.2 Prevention approaches

Prevention methods can be classified into supply management and supply control approaches.

Supply management approaches address the impact of supplier reliability and demand uncertainty on the cost and lead time of different configurations of supplier networks. These include: i) management of supplier relationship, ii) supplier selection process, iii) use of supplier certification programs and iv)allocation of orders among suppliers. Tang (2006a) identifies four types of 'supplier relationships' in terms of: vendor, preferred supplier, exclusive supplier and partner. Each may be differentiated on the basis of contract type, contract length, information exchange, pricing scheme and delivery schedule. Sheffi and Rice (2005) and Tang (2006a) contend that corporate strategy should be aligned with the type of supplier relationship. The latter study addresses the use of various models for the final supplier selection, which incorporate the supplier's quality and the buyer's quality control policies, as well as the buyer's flexibility to shift the order quantity among suppliers dynamically in response to fluctuating exchange rates, when sourcing occurs in a multinational context. Various studies are classified in the area of allocation of orders among different suppliers while accounting for risks such as demand uncertainty, uncertainty in supply yields, supply lead times and supply costs. 'Supplier certification programs' to reduce supply-side quality and delivery reliability problems are suggested as a

prevention approach in Thun and Hoenig (2009). Wu and Olson (2010) use stochastic DEA VaR (value-at-risk) approach and a stochastic dominance model to conduct a vendor evaluation study using twelve criteria over four categories of quality, price, performance and facilities / capabilities. The findings indicate that both the model used and the risk level specified both affect the supplier ranking. However, both models used yield consistent rankings at extremes, for the most efficient and the worst performing vendors.

Supply control approaches may take the form of vertical integration (Klibi et al. 2010), increased stockpiling, use of buffer inventory and excess capacity in production, storage, handling and / or transport or imposing contractual requirements on suppliers (Juttner et al. 2003). With respect to disruptions in inbound or outbound shipments, Sheffi and Rice (2005) advocate building 'tracking and tracing capabilities' to detect disruptions and take corrective action across the supply chain. 'Disruption discovery' approaches, referred to in Blackhurst et al.(2005), include 'predictive analysis' using technologies such as intelligent search agents (data/text mining) and 'dynamic risk index' tools, to search for disruption related information. Early warning signs of potential or increasing risks provided by such tools would be used to highlight these areas within the supply chain that warrant attention.

2.2.3 Mitigation approaches

Among the mitigation approaches, 'flexibility' approaches are aimed at reducing supply cost risks. Juttner et al. (2003) suggest 'localized sourcing' to reduce lead times and improve response times. Tang and Tomlin (2008) suggest the use of quantity flexibility contracts, to mitigate supply commitment risks or the inability to change the order quantity once submitted. Tang (2006b) suggests the use of 'time-based supply contracts' to deal with uncertain wholesale prices imposed by the manufacturer. In a 'time inflexible contract', the buyer must state the purchase time upfront. In a 'time flexible contract', the buyer may observe price movements and decide dynamically when to buy. 'Disruption recovery' strategies, reported in Blackhurst et al. (2005), are about flexible, real time

‘supply chain reconfiguration’ tools, which will take effect once a disruption occurs. An example of such a tool is an adaptive agent or configurable distributed software component that continually realigns goals and processes. Agents are used for task performance, task decomposition and distribution, even resource allocation among the distributed tasks, coordination of mixed initiative supply chain planning, scheduling and partner selection.

‘Redundancy’ approaches such as the use of safety stocks or multiple sourcing are suggested by Thun and Hoenig (2009), who use a survey of the German automotive industry to conclude that redundancy strategies are effective (but inefficient) means to deal with supplier quality and unreliability issues. Tomlin (2006) offers possible risk mitigation strategies for ‘supplier order allocation’ for the case of two alternative suppliers, who differ on reliability, volume flexibility and unit price. This enables rerouting of supply in case the preferred supplier is down. The choice of supplier and the amount of inventory carried depends on the level of uptime.

In Canbolat et al. (2007), a comprehensive set of local and global sourcing risk factors (identified by six departments of a car company) are quantified into metrics. Expert judgments are used to determine the magnitude and the impact of these risks. Then, a process failure mode effects analysis is conducted and simulated to rank causes of failures and failure modes, to calculate total risks in terms of dollars and to evaluate optimum risk mitigation strategies. Swink and Zsidisin (2006) hypothesize that, based on a survey of 224 manufacturing plant managers, the relationship between their focused commitment strategy to suppliers and buyer’s manufacturing performance (measured over five dimensions of cost efficiency, quality, delivery, profitability and market share growth) is non-linear, taking the form of an inverted u-shaped curve, with the exception of ‘quality’ which exhibits a positive linear relation.

(Insert Table 2 here)

2.3. Marketplace

For the risk domain ‘marketplace’, three sources of risk are identified: demand uncertainty, uncertainty in foreign exchange rates and uncertainty in prices of raw material, labor, energy and finished products. The literature on operational approaches used when managing these risks are reviewed in the following sub-sections and summarized in Table 3.

2.3.1 Avoidance approaches

Thun and Hoenig (2009) advocate focusing on products with constant demand and few variants, or focusing on secure markets to manage uncertainty in demand volume and demand mix. Such a ‘focused factory’, which focuses on a narrow product mix for a particular market niche would outperform a conventional plant with a broader mission, since its equipment, support systems, and procedures can concentrate on a limited task for one set of customers, thus generating lower costs and overheads than those of the conventional plant .

2.3.2 Prevention approaches

Prevention approaches incorporate demand management and information management strategies.

Demand management strategies, as described by Tang (2006a), involve shifting demand across time, markets or products. This is to be achieved by offering advance purchase discounts such as those used in travel service reservations, offering price discounts to customers who accept late shipments, phasing out old products and introducing new products. Other examples include ‘product substitution’ which aims to reduce the variance of aggregate demand by offering products with surplus inventory as a substitute for out of stock products and ‘product bundling’ which is used by retailers to force customers to buy a number of products as a bundle, such as computer and printer, shampoo and conditioner, to shape effective demand.

Information management strategies as suggested in Tang (2006a) and Thun and Hoenig (2009) may take the form of quick response systems, use of

RFID, tracking and tracing devices (used to respond to actual demand rather than demand forecasts) for fashion products with short life cycles. For functional products with longer life cycles, these approaches include sharing demand information with supply chain partners, vendor managed inventory and collaborative forecasting and replenishment planning strategies. Juttner et al. (2003) suggest cooperation strategies among supply chain partners to share information on exposures to specific risk sources and prepare joint business continuity plans. Blackhurst et al. (2005) suggest strategies to identify bottlenecks at different nodes of the supply chain. Short-term predictions relating to seasonality of demand, etc. can be used to exploit alternate routing, delaying/expediting product flows and/or inventory positioning. Swafford et. al. (2008) suggest the use of ERP to manage global supply chain activities to deal with supply/demand mismatch risk, shorten product life cycles and customize delivery, speed, mix and volume.

2.3.3 Mitigation approaches

Mitigation approaches include postponement and flexibility strategies.

Postponement strategies are addressed in Juttner et al (2003), Yang et al. (2004), Tang (2006a) and Tang and Tomlin (2008). 'Product development' postponement, which facilitates customization of the final product, is enabled by technologies such as virtual prototypes, web-based voice of the customer method, and automated and distributed service exchange systems. 'Production postponement', which is about downstream positioning of production activities to the distributor, retailer or end user, is useful in markets in which a single product may have multiple derivatives due to different language, culture, government or technological requirements, and greatly reduces inventory carrying and transportation costs. An example on the application of production postponement is the model developed by Cholette (2009). Options of labeling and packaging postponements by a winery to mitigate the variation risk of demands from distinct sales channels are incorporated into a two-stage stochastic linear model. The postponement value is quantified by comparing the expected profits between the

scenarios with and without postponement. The profits in the former scenario are found to be higher by 18%. ‘Logistics postponement’ is conducted by frequent / smaller size shipments or use of a rolling warehouse to achieve savings in inventory which would otherwise have to be stocked at numerous locations and to achieve improved matching of demand and inventory. Yang and Yang (2010) conclude, through drawing insights emerging from the theoretical principles in ‘normal accident theory’, that postponement may offer superior advantages over other risk mitigation strategies employed for supply chain disruptions.

Flexibility strategies, discussed in Sheffi and Rice (2005) and Tang and Tomlin (2008), include ‘flexible pricing strategy via responsive pricing’, which is used to entice customers to products with more secure components to reduce demand risks. ‘Flexible supply strategy via flexible supply contracts’, as reported in Tang (2006a), aims to achieve channel coordination. ‘Wholesale price contracts’ take the form of order up to newsvendor solution which is extended with the flexibility of placing two separate orders before the start of the selling season, hence allowing for demand updating. ‘Buyback contracts’ are used to induce the retailer to order more when faced with demand uncertainty. For products that do not have any buyback value, such as video rentals, ‘revenue sharing contracts’ are used to provide an incentive to the retailer to stock more. ‘Quantity based contracts’ are used to entice retailers to commit their orders in advance to achieve operational efficiency under demand uncertainty. ‘Backup agreements’ are used in the fashion apparel industry to allow the retailer to place his orders in two consecutive stages, after observing a few weeks of sales data, and to offer the flexibility for changing the order at a penalty cost.

‘Contractual flexibility’ as a risk mitigation strategy is reported in reference to the market of specialty chemicals in Reimann and Schiltknecht (2009) as well as in reference to wafer manufacturing at Intel in Vaidyanathan et al. (2005). In the former study, contractual flexibility is the capability of the manufacturer to select the product portfolio and the option of postponing delivery dates for that portion of final demand that is revealed on the due date to protect against cancellation risk / delivery failure penalties imposed by the customer. The

selection of the product portfolio depends on the availability of 'operational flexibility' which is defined as the percentage of available capacity of volume, as well as changeover capabilities. In the latter study at Intel, 'contractual flexibility' refers to the capability of the manufacturer to change order specifications of the required lithography exposure tools from their suppliers to protect against the risk of supply/demand mismatches resulting from short product life cycles. Tang (2006a) suggests that 'flexible process sequencing' can be used to reduce forecast uncertainty by reversing the sequencing of manufacturing processes as exemplified by Benetton's knit-first-dye-later strategy. 'Operational flexibility', (referred to in Kogut and Kulatilaka (1994) and Huchzermeier and Cohen (1996), among others) denotes the capability of switching production among multiple countries to safeguard against exchange rate risk. Spinler and Huchzermeier (2006) use valuation of options on capacity as a measure against seller's cost, buyer's demand and market price uncertainties for storable goods or dated services. The authors show that options contracts offer risk sharing benefits for the buyer and the seller and superior capacity planning. In Mello et al. (1995), 'flexibility in sourcing' is about switching sourcing among multiple countries, in response to sharp movements in exchange rates, thus reducing the need to hedge foreign currency denominated revenue. The level of flexibility and the debt structure determine the level of hedging required. 'Flexibility of production assets' focuses on safeguarding against price uncertainty in power markets (Doege et al. 2009) and derives from the power supplier's entry into a long position in the virtual storage of some part of the production capacity over and above a short position in the constant supply of power.

In Swafford et al. (2008), supply chain flexibility covers procurement, distribution, manufacturing and product development functions and represents abilities to reduce supply chain lead times, ensure production capacity and provide product variety to improve customer responsiveness. 'Supply chain network design' is proposed in Klibi et al. (2010) as a risk mitigation strategy to protect against fluctuations in prices of finished products, raw material prices, energy costs, labor costs and exchange rates. In their two stage stochastic

network design model with recourse anticipation structure, it is assumed that the design variables (such as the number, location and capacity of entities like suppliers, manufacturing plants, distribution and/or sales centers, demand zones and the means of transportation) are to be solved in the first stage. The outcome of the design variables is then observed and the network usage variables provide the recourses necessary to make sure that the design obtained is feasible. 'Resource flexibility' mechanisms, (such as, capacity buffers, production shifting, overtime and subcontracting, safety stock pooling and placement strategies, flexible sourcing contracts), and 'shortage response actions' (such as product substitution, lateral transfers, rerouting shipments or delaying shipments) are suggested as possible response policies. The authors argue that these policies can be reflected into the recourse anticipation structure of the network design model. They cite examples such as defining second stage flow variables between production and distribution centers, if lateral transfers are permitted, or adding recourse variables and constraints to reflect overtime policy, or defining flow variables from suppliers by considering dual sourcing. It is also argued that in order to take 'aversion to value variability' into account, risk measures such as mean-variance or conditional value at risk functions instead of the expected value criterion need to be incorporated into the models.

Kumar et al. (2010) offer optimal operating policies for a global firm conducting business in various countries. A stochastic multi-objective mixed integer programming model is developed. The model attempts to minimize the costs associated with supplier side risks, manufacturer / distributer / retailer risks and demand side risks, as well as, the costs of operating the supply chain. An optimal policy is determined based on the initial information available. In the later stages, by considering changes in risks' expected values, a shift in the flow quantities within the supply chain is determined in order to minimize disruptions and consequently the total cost of operations.

(Insert Table 3 here)

2.4. Environment

The five sources of risk identified for the risk domain 'environment' are: natural disasters, major accidents, political / sociopolitical conditions, willful attacks and regulations. The literature on operational approaches used when managing these risks are reviewed in the following sub-sections. A summary is provided in Table 4.

2.4.1. Avoidance approaches

Klibi et al. (2010) address avoidance approaches for risks associated with product markets, suppliers or facility locations due to the instability of the associated geographical area. Possible strategies proposed are closing some network facilities, delaying an implementation, rejecting an opportunity or using outsourcing for high risk product markets. Cucchiella and Gastaldi (2006) cite 'real options' strategies to protect against risks associated with changes in taxation and local regulations.

2.4.2. *Prevention approaches*

Prevention approaches include 'catastrophe models' which are used in the insurance industry to estimate the location, severity and frequency of potential future natural disasters, offering tradeoffs between economic loss and the probability that a certain level of loss will be exceeded on an annual basis. Klibi et al. (2010) claim that 'supply chain network design' models that incorporate assessment of hazards have not been proposed yet, but qualitative approaches to identify and assess supply chain disruptions are available. A two stage 'supply network design' model to examine the effects of financing, taxation, regional trading zones and local content rules on the design of a global supply chain is developed by Tang (2006a). Sheffi and Rice (2005) state that there is a need for situational awareness and initiative at levels closest to the disruptive event. 'Empowering frontline employees' to take initiative and act quickly on the basis of available information would contribute to the resilience of the supply chain.

2.4.2 Mitigation approaches

These include flexibility and redundancy approaches.

Klibi et. al (2010) suggest incorporating flexibility approaches such as ‘resource flexibility mechanism’ and ‘shortage response actions’ into the supply chain network design as possible risk mitigation strategies, as explained in detail in Section 2.3.3. ‘Resilience strategies’ would necessitate investing in supply chain network structures before they are needed. The authors provide examples of design decisions such as selecting production / warehousing systems that can support several product types and real time changes, choosing suppliers that are partially interchangeable and locating distribution centers to ensure that all customers can be supplied by a backup center with a reasonable service level if the primary supplier fails. On the other hand, redundancy approaches, which involve duplication of network resources in order to continue serving customers while rebuilding after a disruption, are costly to implement according to Klibi et al. (2010). ‘Insurance capacity’ is about maintaining production systems in excess of normal requirements, whereas ‘insurance inventory’ refers to a buffer position kept for critical situations.

A ‘business continuity plan’ is about instantaneous development of alternate suppliers to ensure uninterrupted flow of work. Page (2008) reports that Cisco’s business continuity plan spared its global network from disruption after an earthquake hit China’s Sichuan province, home to a major Cisco supplier. Ratick et al. (2008) suggest a ‘geographical dispersion’ strategy to spread risks associated with single point of failure events, natural and anthropogenic events affecting the value stream (e.g. product contamination) or a node (e.g. damage to a facility). The authors cite Wal-Mart as a model resilient supply chain supported by a sufficient number of stores within reasonable proximity. An automated inventory management system identifies the location of needed resources, while trucks with onboard computers execute the shipments.

(Insert Table 4 here)

3. A synopsis of financial risk management approaches

3.1. Introduction

According to finance literature, there are different motives for risk management. Reducing the firm's expected taxes, costs of financial distress and agency costs associated with debt and equity financing (Smith and Stulz 1985), solving underinvestment problems (Froot et al. 1993), increasing debt capacity (Servaes et al. 2009) and adding value (Mackay and Moeller 2007) are among such motives. These risk management motives are correlated to some extent. Reducing expected taxes increases the firm's cash flow, reducing financial distress costs increases the firm's value and increasing debt capacity allows the firm to raise more capital for new investments.

In this section, we focus on a number of financial risk management approaches that aim to eliminate or mitigate risks that have direct effects upon the operating cash flow of manufacturing firms. Our focus is consistent with the results of the survey of Servaes et al (2009), which identified maximizing of operating cash flow as a high priority item for the participating firms and of Bodnar et al. (1995) which reveals that manufacturing firms rank second among all industries in the usage of derivatives.

Financial risk management approaches include the use of insurance policies, financial derivatives and foreign-currency denominated debt. Financial derivatives, which include forwards, futures, options and swaps, may be used with the objective of hedging or the objective of insuring the risk. Hedging is aimed at eliminating or minimizing the risk exposure at the expense of sacrificing any upside potential. Insuring the risk eliminates or minimizes the adverse consequences at the cost of an insurance premium. While forwards, futures and swaps are used as hedging instruments, options are used to achieve the insurance objective. Servaes et al. (2009) reveals that most CFOs of participating non-financial firms use derivatives to manage risk. We discuss the use of derivatives in the following sections.

3.2. Risk management using derivatives

3.2.1. Types of derivatives

A derivative is a “financial instrument whose value depends on (or derives from) the values of other, more basic underlying variables” (Hull 2006). Japanese yen forwards, futures, and call and put options, for example, are derivatives whose underlying asset is the Japanese yen. The buyer (seller) of a Japanese yen forward contract has the obligation to buy (sell) a fixed number of Japanese yen at a particular date at a fixed exchange rate. Futures contracts are similar to forwards contracts with regards to the obligations of the buyer and the seller. While forward contracts are customized contracts whose terms are fixed by agreement between the buyer and the seller, and are said to trade over-the-counter (OTC), futures contracts are standardized contracts which are traded on futures exchanges. The buyer of a Japanese yen call (put) option has the right to buy (sell) a specified number of Japanese yen sometime in the future at a fixed exchange rate. A swap is an agreement between two parties to exchange a series of cash flows over the term of the swap. One series of cash flows could be fixed, and the other series could be floating, or both series could be floating. The floating cash flow is tied to an index such as an interest rate, currency exchange rate or the price of a particular commodity. Accordingly, swaps may be classified into interest rate swaps, currency swaps and commodity swaps.

A key feature distinguishing the derivative is the ‘linearity’ of the instrument (Froot et al. 1994, Tufano 1996, Servaes et al. 2009). For example, the buyer (seller) of a forward contract is obliged to take (make) delivery of the underlying asset in exchange for a fixed delivery price. If the asset price rises (falls), the buyer (seller) makes a profit and vice versa. Hence, the payoff to the buyer (seller) is linearly dependent on the price of the underlying asset. This is also true in the case of a futures contract and a swap contract, under both of which the participants have certain obligations. This is not true in the case of options, however. A buyer of a call (put) option has the right to exercise the option on or before the expiration date and will do so only if the underlying asset

price is higher (lower) than the option's exercise price. There is no loss when the option is not exercised, but there is a gain when the option is exercised. Hence the payoff to the option buyer is non-linear. When the quantity to be hedged is unknown it is argued that a non-linear financial instrument provides better protection (Brown and Toft 2002, Servaes et al. 2009). Another feature that distinguishes different derivatives is the characteristic of the market. While futures contracts are exchange-traded, forward contracts and swaps are OTC products, while options are traded both on exchanges as well as OTC (Bodnar et al. 1995). This feature shapes the cost structure of the instrument and hence influences the selection decision (Smith and Stulz 1985, Froot et al. 1994, Servaes et al. 2009).

3.2.2. Use of derivatives in risk management

Financial derivatives are used by firms to manage exchange rate risk, interest rate risk and commodity price risk.

Exchange rate risk may be classified into transaction exposure, translation exposure and economic exposure. An example of transaction exposure is that of a Canadian manufacturer which procures some of its input components from Japan and is invoiced in Japanese yen. The manufacturer could hedge the risk of a rise in its input costs due to a rise in the value of the Japanese yen, by buying a forward or futures contract on Japanese yen or buying a call option on Japanese yen. These derivative contracts would rise in value with the increase in value of the Japanese yen, allowing the manufacturer to offset the increased cost of the input components. An example of translation exposure is that faced by a firm which has a foreign subsidiary whose assets and liabilities are denominated in a foreign currency. As the foreign currency exchange rate changes, the consolidated financial statements of the parent firm, which are denominated in the parent's home currency, could record changes in the value of the assets and liabilities of the foreign subsidiary, even if these have not changed when denominated in the foreign currency. Finally, economic exposure to exchange rate changes arises if the sales of a company are threatened by changes in

exchange rates. For example, a Canadian company with a Japan-based competitor could see its global sales decline if the Japanese yen declined in value relative to the Canadian dollar. Froot et al (1994) cite the case of Caterpillar, which saw its "real-dollar sales decline by 45% between 1981 and 1985" when the U. S. dollar increased in value, as an example of a U. S. exporter which could have benefited by using derivatives to hedge its exchange rate risk. It is generally agreed that transaction and economic exposure should be hedged, while translation exposure should be hedged only if the parent company intends to liquidate its foreign subsidiary. Servaes et al (2009) reported that 93% of the participating firms reported an exposure to exchange rate risk, while 82% of the firms use foreign exchange derivatives. Geczy et al. (1997) find that the source of foreign exchange risk influences the type of instrument used. Firms with foreign operations tend to use forwards or a combination of forwards with either futures or options. The surveys by Servaes et al. (2009) and Bodnar et al. (1995) both reveal that forward contracts are the instrument of choice of responding firms, followed by swaps and then OTC options

Interest rate risk arises from a mismatch between the maturity of a firm's interest rate investments and debt. For example, a firm's debt may have three months to maturity, while its investments may have five years to maturity. If the short term interest rate increases, the firm will suffer a loss (Triantis 2000). This is an example of interest rate risk exposure. The company could hedge its interest rate risk by entering into an interest rate swap with a swap dealer, under which it receives interest payments based on the three month interest rate (floating rate) and makes interest payments at a fixed interest rate. A company's current and planned future positions in both borrowings and investments determine its vulnerability to the future change in interest rates (Bacon and Williams 1976). 73% of the firms surveyed by Servaes et al. (2009) reported having at least 10% of debt with floating interest rates, and 79% of the responding firms use interest rate derivatives. The most used derivative is the interest rate swap (Bodnar et al. 1995, Servaes et al. 2009).

Exposure to commodity price risk is not as common as the exposure to exchange rate risk and interest rate risk, but is still a key risk (Froot et al. 1994) and stems from possible changes in the price of input and/or output commodities (Unterschultz 2000). For example, in January, a chocolate factory could take a long position in sugar futures contracts to hedge the price of sugar required for its November production. If the spot price of sugar increases in November, the factory could close out its futures position at a profit, which would offset the higher price that it would pay to buy sugar in the spot market. While 49% of the firms surveyed by Servaes et al. (2009) reported exposure to commodity price fluctuations, and 32% of the firms use commodity derivatives, most of the firms tend to manage commodity price risk with non-financial approaches like contractual arrangements, pricing plans and natural hedges in addition to the standard OTC financial derivative contracts. Bodnar et al. (1995) concluded that there is no financial derivative that dominates commodity price risk management. Instead, commodity price risk is hedged through a variety of financial contracts including swaps, options, futures and forward contracts (Bodnar et al. 1995, Carter et al. 2004). In their case study on fuel hedging Essaddam and Miller (2008) find that both futures contracts and futures options are effective in managing price risk.

3.2.3. Limitations in using derivatives

There are several limitations in using derivatives to manage risk. Firstly, not all assets have corresponding derivatives. For example, there are no futures contracts on jet fuel, which has led airlines to use heating oil futures to manage the price risk of jet fuel. Secondly, the effectiveness of the instrument in hedging risk depends on the correlation between the movements in the price of the asset which is being hedged and the asset underlying the futures. In the case of airline jet fuel hedging, this is the correlation between changes in the price of jet fuel and the price of heating oil. Such a correlation may not always be high enough to make the derivative as effective as desired. Thirdly, the fixed size of the derivative contract may create difficulties in formulating the perfect hedge. For

example, the Japanese yen futures contract traded on the Chicago Mercantile Exchange Group has a size of 12.5 million yen, making it difficult to hedge an exposure of 15 million yen. Fourthly, it is possible that a multinational company anticipates that it will have foreign sales denominated in foreing currency, but has no idea of the magnitude of these sales. Finally, exchange-traded derivatives have specific delivery/expiration dates that may not coincide with the date of the anticipated transaction that a firm wishes to hedge.

4. Distinctions between operational and financial risk management approaches

While operational and financial risk management approaches share a common objective, which is to protect firms from the negative impact of various risks, such approaches also have a number of differences. In the following sub-sections, we describe the major differences which have been highlighted by the reviewed articles. We initially focus on time horizon and cost. Next, we highlight the differences in their impacts on firm's performance and risk exposure. Finally, we present the arguments that characterize operational and financial approaches as substitutes or complements.

4.1. Time horizon

The effects of some financial risk management approaches are largely limited to short term (Chowdhry and Howe 1999, Aabo and Simkins 2005), but do not provide the firm with the strategic position to sustain its competitive edge on a long term basis. For firms exposed to exchange rate risk, use of financial derivatives can mitigate the short term impact of transaction risk but do not prevent the long term effects of competitive risk (Triantis 2000). In addition to the direct transaction advantage, some competitors can also exploit the change in demand for the firm's product as the exchange rate has a direct correlation with the demand for imported products. Unlike financial contracts that have short term effects on risk exposure, the operational approaches, as discussed in Section 2, are implemented to protect the firm from long term risk exposures (Dufey and Srinivasulu 1983, Chowdhry and Howe 1999, Carter et al. 2001, Kim et al. 2006,

among others). At a point in time, many airlines had increased their fuel price hedging horizons to an unprecedented period of six years, as demonstrated in the case of Southwest Airlines (Carter et al. 2006).

4.2. Cost

The long term competitive advantage achieved by employing operational risk management approaches is associated with high costs incurred in opening and closing production facilities, changing product and process designs and many other operational options. The cost of financial hedging (for example, the transaction cost of currency hedging) is much lower than the cost of operational approaches (for example, the costs involved when opening a new production facility in a foreign country) (Chowdhry and Howe 1999, Triantis 2000, Hommel 2003). Operational approaches tend to be very costly due to their strategic nature and firms may opt to implement lower level tactical approaches to avoid such costs. In their survey of non-financial Danish companies, Aabo and Simkins (2005) found that 54% of the surveyed companies would shift their sourcing among suppliers to manage their exposure to the currency rate, compared to only 25% that would take a more permanent action by opening or closing a production facility. However, operational approaches can be cost effective when implemented by firms that are part of a global network with diversified operations (Carter et al. 2001). Such approaches could be less costly than financial derivatives if the exchange rate volatility or the planning horizon increases (Triantis 2000, Hommel 2003). In this context, Huchzermeier and Cohen (1996) argue that as the time horizon gets longer, the cost of financial tools increases while the cost of operational approaches decreases.

4.3. Impact on business performance

The implementation of high cost operational approaches can be justified by the significant positive impact on the firm's performance. Huchzermeier and Cohen (1996) develop a model to value operational flexibility (the options of switching among production plants and / or supply channels) in terms of the

improvement in the expected after-tax profit a firm can achieve after exercising such options (see also Kogut and Kulatilaka 1994). The increase in expected profits would consequently result in an increase in the firm's value (Hommel 2003). The impact of the capacity allocation option on the firm's performance is studied by Ding et al. (2007). By exercising the capability to postpone foreign demand to avoid the adverse effects of the exchange rate change, the firm improves its expected profit and minimizes the exposure risk. This improvement in the firm's profit due to operational flexibility and capacity allocation options seems to be a common impact of operational approaches as argued by Chowdhry and Howe (1999). The authors believe that this impact on profits cannot be achieved by financial hedging contracts alone. This conclusion is supported by Huchzermeier and Cohen (1996). Through a global manufacturing supply chain network model, Huchzermeier and Cohen (1996) found that financial hedging against exchange rate risk does not make a significant change in the expected after-tax profit of the firm. Although Ding et al. (2007) agree that financial tools do not directly increase the firm's profit, they point to the indirect impact of these tools. The authors argue that decreases in the variability of profits caused by financial contracts would motivate firms to invest in more capacity that provides a potential for profit increases.

While the implementation of operational flexibility is shown to increase the firm's value, there are inconsistencies in the findings of empirical studies on the relation between financial hedging and firm's value as observed by Carter et al. (2006). In a theoretical study, Smith and Stulz (1985) explain how hedging should increase firm value. This is confirmed in the empirical study by Allayannis and Weston (2001) who reveal a positive relationship between hedging and firm value. Similarly, Carter et al. (2006) find that financial hedging increases firm values in the airline industry. However, Triantis (2000) contends that operational approaches are better strategies to increase firm value. This perspective is supported by the empirical results of Kim et al. (2006) where the added value due to operational tools was found to be higher than that due to financial instruments. While the positive effects of the financial tools on the firm's value

and profit are argued to be of some significance, the negative effects of the downside risks associated with these tools may prove to be more significant. Huchzermeier and Cohen (1996) argue that the financial hedging tools would have adverse consequences on the firm's ability to enter new markets due to the predictability of its cost structure. Another negative effect can occur when a company decides to hedge fully (say against exchange rate or commodity price risk) resulting in an inability to make value-enhancing moves (Froot et al. 1994).

4.4. Downside risk, upside potential and uncertainty exploitation

While the positive impacts of operational and financial approaches on firm performance are important, the primary objective of these two approaches is to reduce the firm's risk exposure. While both approaches are efficient in reducing exchange rate risk (Carter et al. 2001, Kim et al. 2006), forward contracts deprive the firm of the upside potential in order to eliminate the downside risk (Huchzermeier and Cohen 1996, Triantis 2000). For example, an exporting firm takes a short position in a forward contract on the foreign currency-denominated revenue that the firm expects to receive on a future date, to protect against a possible depreciation of the foreign currency. However, in case of depreciation of the home currency, the exporting firm loses the opportunity to profit as it is bound by the contract to sell the foreign currency at the forward rate rather than the now favorable spot rate. Blume (1971) and Moore (1983) emphasize that upside potential motivates one to take a certain risk in the first place. The loss of the opportunity to increase the cash flow can be costly if, for example, the exporter in the above example has to raise new capital to finance a promising investment (Servaes et al. 2009).

Operational approaches not only reduce risk but also exploit the uncertainties underlying these risks to increase firm's value (Triantis 2000, Ding et al. 2007). Triantis (2000) provides an example of a manufacturer with overseas sales. When the home currency appreciates, the manufacturer experiences a decrease in its cash flow. By operating a production facility in a foreign country, the manufacturer can avoid the decrease in the cash flow by

ensuring that costs and revenues are denominated in the same currency. This allows the manufacturer to outperform its competitors who do not have production facilities in that foreign country. While Huchzermeier and Cohen (1996) consider uncertainty exploitation to be exclusive to operational approaches, Carter et al. (2006), among others, explain how financial hedging tools can also exploit uncertainty. Airline companies that efficiently hedge fuel prices can sustain their projected cash flow during “periods of distress” in which fuel prices are high, which provides them the opportunity to acquire weaker firms. In a survey on non-financial companies, 17% of CFOs find that risk management allows exploitation of trading opportunities in foreign exchange, interest rates and commodities (Servaes et al. 2009).

4.5. Substitutes or complements

Researchers on integrated risk management provide arguments to support operational and financial risk management approaches as both substitutes and complements. Hommel (2003) describes operational diversification as a substitute for financial derivatives when the asset to be hedged and the time horizon are not matched by available derivatives. Aabo and Simkins (2005) report that 52% of the non-financial firms surveyed believe that currency exposure should be managed by operational approaches rather than by financial instruments. Mello et al. (1995) study two cases of risk management and find that the number of financial hedging contracts decreases when the firm’s operational flexibility increases in one case and decreases in the second case. A positive correlation between operational diversification and financial hedging is also observed in Allayannis et al. (2001) and Kim et al. (2006). Chod et al. (2010) study the relationships between two types of operational flexibility and financial hedging under uncertainty in demand for two products. While the authors find postponement flexibility and financial hedging to be substitutes the relationship between product flexibility and financial hedging is found to depend on the correlation between the demands for the two products. The two approaches are

complements when demands are positively correlated and substitutes when the demands are negatively correlated.

5. Integrated operational and financial approaches

The differences between operational and financial risk management approaches in terms of cost, time horizon, firm performance and risk support the need to integrate these two approaches to counterbalance the shortcomings of one approach by the benefits of the other. For example, limitations of financial instruments in reducing competitive risk can be overcome by a strategic operational initiative. The high cost of operational approaches can be alleviated by exploiting low cost financial instruments which are equally effective. In addition, operational and financial approaches can, when combined, manage risks that cannot be managed by a single approach. Firms are continuously exposed to a bundle of risks that cannot be reduced by financial instruments alone (Miller 1992) but can only be managed by an integrated approach. We highlight these possibilities in the following review of the rather scanty literature on integrated operational and financial risk management approaches.

Weiss and Maher (2009) examine the effects of fuel hedging by focusing on the hedging capability of nine U.S. airline companies. The results show that fuel hedging does not significantly contribute to the firm's hedging capability. The authors justify this finding by arguing that fuel hedging cannot protect airline companies against variations in demand for airline services. This demand uncertainty is one of the various operating problems that cannot be effectively tackled by financial instruments alone (Aabo and Simkins 2005). Chowdhry and Howe (1999) argue that a financial hedging tool can be effective in hedging exchange rate risk if demand is deterministic. It is therefore reasonable to conclude that in the case of uncertain demand, exchange rate risk should be managed by an integrated operational and financial approach.

Financial derivatives support the implementation of operational approaches. Allayannis et al. (2001) and Faseruk and Mishra (2008) conclude that operational hedging in the form of geographical dispersion does not protect

multinational firms from exchange rate risk unless it is in addition to the use of currency derivatives and foreign debt. Triantis (2000) presents an example of a manufacturer who uses his production switching capability to mitigate his exposure to currency fluctuations. If the home currency depreciates, currency derivatives can offset the reduction in value of the overseas facility. Hommel (2003) describes such use of financial instruments as a 'buffer' for the implementation of operational approaches. Dufey and Srinivasulu (1983) explain that hedging eliminates risks of unexpected changes in the exchange rate, allowing operational approaches to deal with variations in business activity. The implementation of financial tools would also have an impact on operational decisions. Gaur and Seshadri (2005) demonstrate how financial hedging allows a retailer to increase its optimal inventory level for a product when the demand for that product is correlated with the price of the asset underlying the financial instrument.

The complementary effects of operational and financial approaches make the integrated implementation of these approaches more valuable than their separate implementation. Carter et al. (2001) report that the integrated approaches reduce the firm's risk exposure more effectively, due to the ability to manage both long and short term risk exposure. Ding et al. (2007) show that the simultaneous use of currency options and the capacity allocation options result in better performance measures than the use of each tool separately. Mello et al. (1995) find that firm value is highest when operational flexibility is high and financial hedging is used. Faseruk and Mishra (2008) argue that not only does the integrated strategy increase firm value, but that the utilization of a single approach in an isolated manner may not even increase the firm's value at all. This is consistent with an earlier finding by Miller (1992) who argued that the implementation of one approach would give 'suboptimal' results since the two approaches are interrelated.

We summarize in Table 5 the various combinations of operational and financial approaches along with the type of risk under which these combinations have been applied in the literature.

(Insert Table 5 here)

6. Areas for future research

Table 5 facilitates making some observations as to the current state of the integrated SCRM literature. Exchange rate risk exposure is mostly incorporated in the models reported and most models use currency derivatives. As discussed in Section 3, commodity price risk and interest rate risk are also key risks to be managed. Hence, new models need to be developed to further incorporate these risks in integrated SCRM modelling. On the operational side, most often, three types of operational approaches (geographic dispersion, switching production and capacity allocation postponement) are integrated with financial instruments. Considering the large number of available operational strategies which were discussed in Section 2, the research opportunities of integrating these other operational approaches (such as, inventory management) with financial instruments could be substantial. The reviewed quantitative models tend to focus on downstream operations and mostly involve manufacturing plants and those markets in which they sell. Designing models that also incorporate the upstream partners of a firm could narrow this gap in the literature. It is also observed that the reviewed models have the common objective of optimizing a firm's performance and hence are very much focal firm centric. As argued by Juttner et al. (2003) and Rao and Goldsby (2009), among others, the objective of supply chain risk management is to reduce the vulnerability of the supply chain as a whole rather than of the focal firm. While building models that improve the performance of a supply chain as a whole could be challenging, the models would significantly contribute to developing novel risk management strategies that could provide contemporary supply chains a competitive edge.

References

1. Aabo, T. and Simkins, B.J., 2005. Interaction between real options and financial hedging: fact or fiction in managerial decision-making. *Review of Financial Economics,* 14 (3, 4), 353-369.
2. Allayannis, G. and Weston, J., 2001. The use of foreign currency derivatives and firm market value. *The Review of Financial Studies,* 14 (1), 243-276.
3. Allayannis, G., Ihrig, J. and Weston, J.P., 2001. Exchange-rate hedging: Financial versus operational strategies. *The American Economic Review,* 91 (2), 391-395.
4. Bacon, P.W. and Williams, R.E., 1976. Interest rate futures: New tool for the financial manager. *Financial Management,* 5 (1), 32-38.
5. Bandaly, D., Kahyaoglu, Y., Satir, A. and Shanker, L., 2011. Supply chain risk management – I: Conceptualization, framework and planning process. *International Journal of Production Research* (under editorial review).
6. Blackhurst, J., Craighead, C.W., Elkins, D. and Handfield, R.B., 2005. An empirically derived agenda of critical research issues for managing supply-chain disruptions. *International Journal of Production Research,* 43 (19), 4067-4081.
7. Blackhurst, J., Wu, T. and O'Grady, P., 2004. Network-based approach to modelling uncertainty in a supply chain. *International Journal of Production Research,* 42 (8), 1639.
8. Blume, M.E., 1971. On the assessment of risk. *Journal of Finance,* 26 (1), 1-10.
9. Bodnar, G.M., Hayt, G.S., Marston, R.C. and Smithson, C.W., 1995. Wharton survey of derivatives usage by US non-financial firms. *Financial Management,* 24 (2), 104-114.
10. Bradley, K. and Moles, P., 2002. Managing strategic exchange rate exposures: Evidence from UK firms. *Managerial Finance,* 28 (11), 28-42.
11. Brown, G.W. and Toft, K.B., 2002. How firms should hedge. *The Review of Financial Studies,* 15 (4), 1283-1324.
12. Canbolat, Y.B., Gupta, G., Matera, S. and Chelst, K.,2007. Analyzing risk in sourcing design and manufacture of components and sub-systems to emerging markets. *International Journal of Production Research*, 46 (18), 5145-5164.
13. Carter, D.A., Pantzalis, C. and Simkins, B.J., 2001. Firmwide risk management of foreign exchange exposure by US multinational corporations. Available from: http://ssrn.com/abstract=255891.
14. Carter, D.A., Rogers, D.A. and Simkins, B.J., 2004. Fuel hedging in the airline industry: The case of Southwest Airlines. Available from: http://ssrn.com/abstract=578663.
15. Carter, D.A., Rogers, D.A. and Simkins, B.J., 2006. Does hedging affect firm value? Evidence from the US airline industry. *Financial Management,* 35 (1), 53-86.
16. Chowdhry, B. and Howe, J.T.B., 1999. Corporate risk management for multinational corporations: Financial and operational hedging policies. *European Finance Review*, 2, 229-246.

17. Cucchiella, F. and Gastaldi, M., 2006. Risk management in supply chain: A real option approach. *Journal of Manufacturing Technology Management,* 17 (6), 700-720.
18. Chod, J., Rudi, N. and Van Mieghem, J.A., 2010. Operational flexibility and financial hedging: Complements or substitutes? *Management Science,* 56 (6), 1030-1045.
19. Cholette, S., 2009. Mitigating demand uncertainty across a winery's sales channels through postponement. *International Journal of Production Research*, 47 (13), 3587-3609.
20. Ding, Q., Dong, L. and Kouvelis, P., 2007. On the integration of production and financial hedging decisions in global markets. *Operations Research,* 55 (3), 470-489.
21. Doege, J., Fehr, M., Hinz, J., Lüthi, H. and Wilhelm, M., 2009. Risk management in power markets: The hedging value of production flexibility. *European Journal of Operational Research,* 199 (3), 936-943.
22. Dufey, G. and Srinivasulu, S.L., 1983. The case for corporate management of foreign exchange risk. *Financial Management,* 12 (4), 54-62.
23. Essaddam, N. and Miller, D., 2008. An application of hedging fuel price risk in the Canadian department of national defence. *The Business Review, Cambridge,* 9 (2), 360-365.
24. Faseruk, A. and Mishra, D.R., 2008. An examination of US dollar risk management by Canadian non-financial firms. *Management Research News,* 31 (8), 570-582.
25. Froot, K.A., Scharfstein, D.S. and Stein, J.C., 1993. Risk management: coordinating corporate investment and financing policies. *The Journal of Finance,* 48 (5), 1629-1658.
26. Froot, K.A., Scharfstein, D.S. and Stein, J.C., 1994. A framework for risk management. *Journal of Applied Corporate Finance,* 7 (3), 22-32.
27. Gaur, V. and Seshadri, S., 2005. Hedging inventory risk through market instruments. *Manufacturing and Service Operations Management*, 7 (2), 103-120.
28. Geczy, C., Minton, B.A. and Schrand, C., 1997. Why firms use currency derivatives. *The Journal of Finance,* 52 (4), 1323-1354.
29. Hommel, U., 2003. Financial versus operative hedging of currency risk. *Global Finance Journal,* 14 (1), 1-18.
30. Huchzermeier, A. and Cohen, M.A., 1996. Valuing operational flexibility under exchange rate risk. *Operations Research,* 44 (1), 100-113.
31. Hull, J.C., 2006. *Options, futures, and other derivatives*. 6th ed. New Jersey: Prentice-Hall.
32. Juttner, U., 2005. Supply chain risk management: Understanding the business requirements from a practitioner perspective. *International Journal of Logistics Management,* 16 (1), 120-141.
33. Juttner, U., Peck, H. and Christopher, M., 2003. Supply chain risk management: Outlining an agenda for future research. *Supply Chain Management Review,* 6 (4), 197-210.

34. Khan, O. and Burnes, B., 2007. Risk and supply chain management: Creating a research agenda. *International Journal of Logistics Management,* 18 (2), 197-216.
35. Kim, Y.S., Mathur, I. and Nam, J., 2006. Is operational hedging a substitute for or a complement to financial hedging? *Journal of Corporate Finance,* 12, 834-853.
36. Klibi, W., Martel, A. and Guitouni, A., 2010. The design of robust value-creating supply chain networks: A critical review. *European Journal of Operational Research,* 203 (2), 283-293.
37. Kogut, B. and Kulatilaka, N., 1994. Operating flexibility, global manufacturing, and the option value of a multinational network. *Management Science,* 40 (1), 123-139.
38. Kumar, S.K., Tiwari, M. K. and Babiceanu, R.F., 2010. Minimization of supply chain cost with embedded risk using computational intelligence approaches. *International Journal of Production Research*, 48 (13), 3717-3739.
39. Mackay, P. and Moeller, S.B., 2007. The value of corporate risk management. *The Journal of Finance,* 62 (3), 1379-1419.
40. Manuj, I. and Mentzer, J., 2008a. Global supply chain risk management strategies. *International Journal of Physical Distribution & Logistics Management,* 38 (3), 192-223.
41. Manuj, I. and Mentzer, J., 2008b. Global supply chain risk management. *Journal of Business Logistics,* 29 (1), 133-156.
42. Mello, A.S., Parsons, J.E. and Triantis, A.J., 1995. An integrated model of multinational flexibility and financial hedging. *Journal of International Economics,* 39 (1-2), 27-51.
43. Miller, K.D., 1992. A framework for integrated risk management in international business. *Journal of International Business Studies,* 23 (2), 311-331.
44. Moore, P.G., 1983. *The business of risk*. Cambridge: Cambridge University Press.
45. Page, P., 2008. Risk management is critical for protecting supply chains: Cisco's plan spared its global network from disruption after earthquake in Sichuan. *Shipping Digest*, 11-13.
46. Rao, S. and Goldsby, T.J., 2009. Supply chain risks: A review and typology. *International Journal of Logistics Management,* 20 (1), 97-123.
47. Ratick, S., Meacham, B. and Aoyama, Y., 2008. Locating backup facilities to enhance supply chain disaster resilience. *Growth and Change,* 39 (4), 642-666.
48. Reimann, M. and Schiltknecht, P., 2009. Studying the interdependence of contractual and operational flexibilities in the market of specialty chemicals. *European Journal of Operational Research,* 198 (3), 760-772.
49. Servaes, H., Tamayo, A. and Tufano, P., 2009. The theory and practice of corporate risk management. *Journal of Applied Corporate Finance,* 21 (4), 60-78.

50. Sheffi, Y. and Rice, J.B.Jr., 2005. A supply chain view of the resilient enterprise. *MIT Sloan Management Review,* 47 (1), 41-48.
51. Smith, C.W. and Stulz, R.M., 1985. The determinants of firms' hedging policies. *Journal of Financial and Quantitative Analysis,* 20 (4), 391-405.
52. Spinler, S. and Huchzermeier, A., 2006. The valuation of options on capacity with cost and demand uncertainty. *European Journal of Operational Research,* 171 (3), 915-934.
53. Swafford, P., Ghosh, S. and Murthy, N., 2008. Achieving supply chain agility through IT integration and flexibility. *International Journal of Production Economics,* 116 (2), 288-297.
54. Swink, M. and Zsidisin, G., 2006. On the benefits and risks of focused commitment to suppliers. *International Journal of Production* Research, 44 (20), 4223-4240.
55. Tang, C. and Tomlin, B., 2008. The power of flexibility for mitigating supply chain risks. *International Journal of Production Economics,* 116 (1), 12-27.
56. Tang, C., 2006a. Perspectives in supply chain risk management. *International Journal of Production Economics,* 103 (2), 451-488.
57. Thun, J. and Hoenig, D., 2009. An empirical analysis of supply chain risk management in the German automotive industry. *International Journal of Production Economics*, In Press, Corrected Proof.
58. Tomlin, B., 2006. On the value of mitigation and contingency strategies for managing supply chain disruption risks. *Management Science,* 52 (5), 639-657.
59. Triantis, A.J., 2000. Real options and corporate risk management. *Journal of Applied Corporate Finance,* 13 (2), 64-73.
60. Tufano, P., 1996. Who manages risk? An empirical examination of risk management practices in the gold mining industry. *The Journal of Finance,* 51 (4), 1097-1137.
61. Turnbull, L., 2007. Compliance and global logistics. *Canadian Transportation Logistics*, 110 (8), 46.
62. Unterschultz, J.R., 2000. Managing market risk in Western Canadian agriculture. *Canadian Journal of Agricultural Economics,* 48 (4), 527-537.
63. Vaidyanathan, V., Metcalf, D. and Martin D., 2005. Using capacity options to better enable our factory ramps. *Intel Technology Journal*, 9 (3), 185-191.
64. Weiss, D. and Maher, M., 2009. Operational hedging against adverse circumstances. *Journal of Operations Management,* 27 (5), 362-373.
65. Wong, K.P., 2007. Operational and financial hedging for exporting firms. *International Review of Economics and Finance,* 16 (4), 459-470.
66. Wu, D.D. and Olson, D., 2010. Enterprise risk management: a DEA VaR approach in vendor selection. *International Journal of Production Research*, 48 (16), 4919-4932.
67. Yang, B., Burns, N. D. and Backhouse, C. J., 2004. Management of uncertainty through postponement. *International Journal of Production Research*, 42 (6), 1049-1064.

68. Yang, B. and Yang, Y., 2010. Postponement in supply chain risk management. *International Journal of Production Research*, 48 (7), 1901-1912.

Supply chain risk management – II: A review of individual and integrated operational and financial approaches

Table	Caption
Table 1	Risk management approaches for the risk domain 'internal operations'
Table 2	Risk management approaches for the risk domain 'external stakeholders'
Table 3	Risk management approaches for the risk domain 'marketplace'
Table 4	Risk management approaches for the risk domain 'environment'
Table 5	Risks managed by integrated operational and financial approaches

Table 1. Risk management approaches for the risk domain 'internal operations'.

Sources of Major Risks	Identified Risks	Risk Management Approach			Functional Area(s)
		Avoidance	Prevention	Mitigation	
Process uncertainty	Products causing safety hazards (60)		Vendor selection, supply chain visibility (61)	Reverse logistics: efficient transportation strategies, modal flexibility (61)	Sourcing , Logistics , Information Systems (61)
	Machinery / equipment breakdowns (57)			Improve flexibility (57)	Manufacturing (57)
	Capacity / time / quality (17, 55)	Real options: defer, outsource, scale down, abandon (17)	Real options: stage, explore, lease, growth (17)	Flexible process strategy via flexible manufacturing process (50)	Process Design (55), Strategy (17)
	Delivery / processing delays (50)			Conversion flexibility (50)	Process Design (50)
	Lead time uncertainty (7)		Model based decision support system (7)		Manufacturing (7), Procurement (7)
Information system failures	Information delays / disruptions (17, 33)	Real options: defer, outsource, scale down, abandon (17)		Conversion flexibility (50)	Strategy (17), Information Systems, Sourcing, Manufacturing (33)
Labor uncertainty	Labor strikes, employee turnover (33, 50)				

Table 2. Risk management approaches for the risk domain 'external stakeholders'.

Sources of Major Risks	Identified Risks	Risk Management Approach			Functional Area(s)
		Avoidance	Prevention	Mitigation	
Supplier reliability	Quality / delivery reliability (12, 17, 47, 54, 55, 56, 57, 66)	Real options: defer, outsource, scale down, abandon (17)	Supply network design (56); Alignment of strategy with relationship (50, 56); Supplier selection process (56, 66); Supplier certification programs (40, 57); Backward integration (36, 40)	Build up redundancies: safety stocks, multiple suppliers (57); Supplier order allocation: sourcing mitigation / contingent rerouting / inventory mitigation / acceptance (54, 58); Sourcing from emerging markets (12)	Sourcing (12, 54, 56, 66), Strategy (17, 56), Supply and Procurement (50)
	Business continuity (45, 56, 57); Risk of particular segment of supply chain being crippled (6)		Supplier selection process (56)	Disruption recovery strategies: Supply chain reconfiguration (6) / Supply chain redesign (6)	Sourcing (42, 56), Strategy (6)
	Supply yield / capacity uncertainty (56)		Supply network design (56); Alignment of strategy with relationship (44, 50, 56); Supplier order allocation (56)		
	Lead time uncertainty (12, 56)				Sourcing (12)
	Price uncertainty (54, 55, 56, 66)		Supplier selection (66)	Flexible supply strategy via multiple suppliers (54, 55)	Sourcing (54, 56, 66)
	Commitment (54, 55)			Flexible (time-based) supply contracts (55, 56); Supplier order allocation (54)	Sourcing (54, 55)
Distribution	Shipment disruptions (inbound / outbound) (50)		Ability of information systems to detect disruption and take corrective action (50); Disruption discovery strategies: predictive analysis: intelligent search agents, dynamic risk index tools (6)		Information Management (50)
Network	Chaos, lack of ownership, inertia (33)		Control strategies (33)		Operations (33)

Table 3. Risk management approaches for the risk domain 'marketplace'.

Sources of Major Risks	Identified Risks	Risk Management Approach			Functional Area(s)
		Avoidance	Prevention	Mitigation	
Uncertainty in demand	Volume (55, 56)	Focus on products with constant demand and few variants; Focus on secure markets (57)	Shifting demand across time: advance commitment discount program (56)	Price postponement strategy / shifting demand across time, revenue/yield management, delivery postponement (56); Flexible supply strategy via flexible supply contracts (55, 56)	Manufacturing / Product Differentiation (55), Demand Management (56)
	Mix (55, 56, 67)		Shifting demand across products: product substitution/product bundling (56)		Demand Management (56)
	Price (20, 21, 56)			Flexibility of production assets (1, 21)	Sourcing (56), Finance (21)
	Contract uncertainty (48); Cancellation risk			Operational flexibility, contractual flexibility (48)	Demand Management, Manufacturing (48)
	Rapid change in technologies and product markets (17); Short product life cycles (17, 50, 56, 67); Customization (19, 50, 53, 63, 67, 68)		Shifting demand across markets: product rollover strategy (56); Real options: lease, explore, scale up (17); Contract flexibility (63)	Financial hedging: options contract (63) ; Flexible pricing strategy via responsive pricing (55); Flexible product strategy via postponement (55); Postponing product differentiation via standard components, modular design, postponement of operations, re-sequencing of operation (19, 56, 68); Postponement strategies: product development postponement, production postponement, purchasing postponement, logistics postponement (50, 67)	Demand Management (19, 56, 68), Strategy (17), Sourcing (63), Finance (63), Manufacturing (53, 55, 56, 67), Product Design (53, 67), Logistics, Distribution/marketing (50, 53)
	Information (6, 50, 53, 56, 68); Bullwhip effect (56)		Information management strategies: quick response system, information sharing, vendor managed inventory, collaborative forecasting (56); Disruption discovery strategies: improving transparency, information availability within the supply chain, e.g. RFID, tracking and tracing devices (6, 57); Cooperation strategies (33); Capacity visibility at different nodes (6); Use of ERP for managing global operations, improving supply chain agility (53)	Improving supply chain flexibility (53); Postponement of operations (68)	Information Management (6, 53, 57, 68), Sourcing (53, 57)
Currency exchange rate fluctuation	Transaction risk (10, 35, 59)		Supplier order allocation (56)	Operational flexibility (option value of excess capacity) (30, 37, 52, 56); Flexibility in sourcing (1, 42); Futures, forwards and options (1, 2, 3, 9, 16, 20, 28, 29, 30, 35, 38, 42, 49, 59)	Sourcing (56), Strategy (37, 56), Finance (30, 37, 42)
	Translation risk (10, 59)				
	Competitive risk (10, 17, 35, 59)	Real options: defer, outsource, scale down, abandon (1, 17)	Real options: stage, explore, lease, growth (1, 17)	Geographic diversification (13, 29, 35)	Strategy (17)
Marketplace randomness	Fluctuations in prices of finished products, raw materials, labor, energy, interest rate (9, 36, 38, 49, 59)			Supply chain network design: resource flexibility mechanism, shortage response actions (36, 38); Futures, forwards, options and swaps (4, 9, 14, 15, 23, 31, 49, 62)	Strategy (36, 68)

Table 4. Risk management approaches for the risk domain 'environment'.

Sources of Major Risks	Identified Risks	Risk Management Approach			Functional Area(s)
		Avoidance	Prevention	Mitigation	
Natural disasters	Hurricanes, floods, earthquakes, forest fires (33, 36, 50, 57)	Resilience strategies: closing facilities, delaying implementation, outsourcing (36); Geographical avoidance (33, 57)	Employee empowerment / top level involvement (50)	Supply chain network design: responsiveness policies: resource flexibility mechanisms, shortage response actions, Resilience strategies: building up flexibilities and redundancies (36), Geographical dispersion (45, 47)	Change Management (50), Sourcing, Production, Inventory Management, Logistics (36)
Major accidents	Epidemics, chemical/nuclear spills-product contamination (33, 47, 50, 57)				Strategy (47)
Political / sociopolitical conditions	Instability of the geographical area (36)			Investing in flexible / redundant network structure (36)	Strategy (33, 36, 57), Logistics (36)
Willful attacks	Terrorist attacks, political coup (33, 36, 57)				
Regulations	Financing, taxation, regional trading zones, local content rules (17, 56)	Real options: defer, outsource, scale down, abandon (17)	Supply network design (56)		Strategy (17, 56)
	Regulations affecting product development / product launching (17)	Real options: defer, outsource, scale down, abandon (17)			Strategy (17)

Table 5. Risks managed by integrated operational and financial approaches.

	Risks managed by integrated operational and financial approaches				
Operational / Financial	Geographic dispersion	Switching production	Capacity allocation postponement	Inventory management	Operational options (various)
Financial hedges (various)	Exchange rate (21)			Inventory risk due to demand uncertainty (27)	Exchange rate (1), Severe disruptions (58)
Currency derivatives (various)	Exchange rate (3, 12, 31)	Exchange rate / demand (15)	Exchange rate / demand (17)		
Currency forwards	Exchange rate (25)	Exchange rate (37)			
Currency options		Exchange rate (25)			
Exotic derivatives			Exchange rate (59)		
Foreign debt	Exchange rate (3)				Exchange rate (10)