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A review of enterprise risk management in supply chain

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Abstract

Purpose – The purpose of this paper is to review published approaches to supply chain risk management, to include identification and classification of types of risks, cases, and models. Specific aspects of risk in supply chains involving China are also addressed.

Design/methodology/approach – Literature review provides sources which are synthesized.

Findings – A generic framework is identified, then categorizations of supply chain risks are compared. Cases and models applied to the study of supply chain risk are reviewed briefly. A review of Chinese risk in the supply chain context is provided.

Originality/value – This review includes many current studies, and is a source of useful references for those examining supply chain risk.

Keywords Cybernetics, Risk management, Supply chain management, China

Paper type Literature review

1. Introduction

All human endeavors involve uncertainty and risk. Mitroff and Alpaslan (2003) categorized emergencies and crises into three categories: natural disasters, malicious activities, and systemic failures of human systems. Nature does many things to us, disrupting our best-laid plans and undoing much of what humans have constructed. Malicious acts are intentional on the part of fellow humans who are either excessively competitive or who suffer from character flaws. The third category is probably the most common source of crises: unexpected consequences arising from overly complex systems (Perrow, 1984). Examples of such crises include Three Mile Island in Pennsylvania in 1979 and Chernobyl in 1986 within the nuclear power field, the chemical disaster in Bhopal India in 1984, the Exxon Valdez oil spill in 1989, the Ford-Firestone tire crisis in 2000, and the Columbia space shuttle explosion in 2003. The financial world is not immune to systemic failure, as demonstrated by Barings Bank collapse in 1995, the failure of Long-Term Capital Management in 1998, and the sub-prime mortgage bubble implosion leading to near-failure (hopefully no worse than near-failure) in 2008.

All organizations need to prepare themselves to cope with crises from whatever source. In an ideal world, managers would identify everything bad that could happen to them, and develop a contingency plan for each of these sources of crisis. It is a good idea to be prepared. However, crises by definition are almost always the result of nature, malicious humans, or systems catching us unprepared (otherwise there may not have been a crisis). We need to consider what could go wrong, and think about what we

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might do to avoid problems. We cannot expect to cope with every contingency, however, and need to be able to respond to new challenges.

This paper will focus on supply chain risk management. The next section will review the types of risks faced within supply chains as identified by recent sources. We will then look at processes proposed to enable organizations to identify, react to, and cope with challenges that have been encountered. This will include looking at risk mitigation options. One option explored in depth will be the application of value-focused analysis to supply chain risk. We will then seek to demonstrate points with cases from the literature. We will conclude with an overview.

2. Supply chain risk frameworks

There is a rapidly growing body of literature concerning supply chain risk management, to include special issues in *Journal of Operations Management* (Narasimhan and Talluri, 2009), *Production Planning & Control* (Wu and Olson, 2009b) and in *Journal of Supply Chain Management* (Flynn, 2009). This literature involves a number of approaches, including some frameworks, categorization of risks, processes, and mitigation strategies. Frameworks have been provided by many, to include Khan and Burnes (2007) who proposed a research agenda to lead empirical support for the many theoretical works they found, and Tang and Tomlin (2008) who presented a unified framework around supply chain flexibility. Roth *et al.*'s (2008) framework concerned food recalls from China. Nishat Faisal *et al.* (2007) gave a framework focusing on risk to small and medium-sized enterprises, while Williams *et al.* (2008) did the same for a focus on supply chain security against terrorist acts. Autry and Bobbitt (2008) analyzed structured managerial interviews concerning supply chain security, and identified factors most related to those managers' views of supply chain security.

We begin with a general framework. Ritchie and Brindley (2007) viewed five major components to a framework in managing supply chain risk.

Risk context and drivers

Supply chains can be viewed as consisting of primary and secondary levels. The primary level chain involves those that have major involvement in delivery of goods and services (Wal-Mart itself and its suppliers). At the secondary level participants have a more indirect involvement (those who supply vendors who have contracts with Wal-Mart, or Wal-Mart's customers). The primary level participants are governed by contractual relationships, obviously tending to be more clearly stated. Risk drivers can arise from the external environment, from within an industry, from within a specific supply chain, from specific partner relationships, or from specific activities within the organization.

Risk drivers arising from the external environment will affect all organizations, and can include elements such as the potential collapse of the global financial system, or wars. Industry specific supply chains may have different degrees of exposure to risks. A regional grocery will be less impacted by recalls of Chinese products involving lead paint than will those supply chains carrying such items. Supply chain configuration can be the source of risks. Specific organizations can reduce industry risk by the way they make decisions with respect to vendor selection. Partner specific risks include consideration of financial solvency, product quality capabilities, and compatibility and capabilities of vendor information systems. The last level of risk drivers relate to

internal organizational processes in risk assessment and response, and can be improved by better equipping and training of staff and improved managerial control through better information systems.

Risk management influencers

This level involves actions taken by the organization to improve their risk position. The organization's attitude toward risk will affect its reward system, and mold how individuals within the organization will react to events. This attitude can be dynamic over time, responding to organizational success or decline.

Decision makers

Individuals within the organization have risk profiles. Some humans are more risk averse, others more risk seeking. Different organizations have different degrees of group decision making. More hierarchical organizations may isolate specific decisions to particular individuals or offices, while flatter organizations may stress greater levels of participation. Individual or group attitudes toward risk can be shaped by their recent experiences, as well as by the reward and penalty structure used by the organization.

Risk management responses

Each organization must respond to risks, but there are many alternative ways in which the process used can be applied. Risk must first be identified. Monitoring and review requires measurement of organizational performance. Once risks are identified, responses must be selected. Risks can be mitigated by an implicit tradeoff between insurance and cost reduction. Most actions available to organizations involve knowing what risks the organization can cope with because of their expertise and capabilities, and which risks they should outsource to others at some cost. Some risks can be dealt with, others avoided.

Performance outcomes

Organizational performance measures can vary widely. Private for-profit organizations are generally measured in terms of profitability, short-run and long-run. Public organizations are held accountable in terms of effectiveness in delivering services as well as the cost of providing these services. Kleindorfer and Saad (2005) gave eight key drivers of disruption/risk management in supply chains:

(1) corporate image;
(2) liability;
(3) employee health and safety;
(4) cost reduction;
(5) regulatory compliance;
(6) community relations;
(7) customer relations; and
(8) product improvement.

In normal times, there is more of a focus on high returns for private organizations, and lower taxes for public institutions. Risk events can make their preparation in dealing with risk exposure much more important, focusing on survival (Wu and Olson, 2009a).

3. Cases and models

The research literature is very heavily populated by studies of supply chain risk in recent years. Sodhi and Lee (2007) reported risk management at Samsung Electronics, describing the risk-mitigation steps used to deal with risks in all categories of risk appropriate to that firm's operations. Ojala and Hallikas (2006) reported experiences in the electronic and metal sector supply chains. Nagali *et al.* (2008) described the process and software developed to measure and manage Hewlett-Packard's procurement risk. Schoenherr *et al.* (2008) reviewed a case study of a firm considering Mexican, Chinese, and US alternatives to provide finished goods for a US manufacturer. Khan *et al.* (2008) reported empirical research involving the clothing manufacturing and fashion retail industries. Automotive supply chain cases were reported by Berry and Collier (2007) and by Blackhurst *et al.* (2008). Ritchie and Brindley (2007) reported risk analysis in a supply chain involving agricultural equipment, as well as a second case involving construction. Aerospace industry supply chain cases were reported by Zsidisin and Smith (2005) and VanderBok *et al.* (2007). Note that this is only the tip of the iceberg, meant to give some flavor of the variety of supply chain domains that have been analyzed for risk.

Many different types of models have been proposed in the literature. Because of the uncertainty involved, statistical analysis and simulation is very appropriate to consider supply chain risk. We will only report a few of the many studies, relying on more recent articles. Li and Chandra (2007) proposed used of Bayesian analysis to model information and knowledge integration within complex networks. Simulation was proposed in a number of studies, to include discrete-event simulation to estimate survival over long-range periods given assumed probabilities of supply chain linkage failure (Klimov and Merkuryev, 2008). Wu and Olson (2008) used Monte Carlo simulation to evaluate risks associated with vendor selection, following up on similar modeling from many sources. System dynamics models have been widely used, especially with respect to the bullwhip-effect (Towill and Disney, 2008 as only one recent example) and to model environmental, organizational, and network-related risk issues (Kara and Kayis, 2008).

Other modeling approaches have been applied to supply chain risk as well. Tang *et al.* (2008) applied a fuzzy genetic algorithm approach to evaluate logistics strategies to lower supply chain risks. Bogataj and Bogataj (2007) used parametric linear programing based on net present value to estimate supply chain vulnerability. Goh *et al.* (2007) applied a stochastic bi-criterion algorithm to analyze a multi-stage global network problem with objectives of profit maximization and risk minimization. Many studies applied analytic hierarchy process, to include recent studies such as assessment of an offshoring decision (Schoenherr *et al.*, 2008), the similar decision to select suppliers (Kull and Talluri, 2008; Schoenherr *et al.*, 2008), overall supply chain risk evaluation (Gaudenzi and Borghesi, 2006), and inbound supply risk evaluation (Wu *et al.*, 2006). Blackhurst *et al.* (2008) presented a study considering multiple objectives for supplier risk assessment utilizing a generic multiple criteria analysis similar to the simple multiattribute rating theory method.

4. Risk categories within supply chains

Supply chains involve many risks. Cucchiella and Gastaldi (2006) divided supply chain risks into categories of internal (involving such issues as capacity variations, regulations, information delays, and organizational factors) and external (market prices, actions of

competitors, manufacturing yield and costs, supplier quality, and political issues). Kleindorfer and Saad (2005) categorized these into risks arising from coordinating complex systems of supply and demand (internal), and disruptions (external). Specific supply chain risks considered by various studies are given in Table I.

Supply chain organizations thus need to worry about risks from every direction. In any business, opportunities arise from the ability of that organization to deal with risks. Most natural risks are dealt with either through diversification and redundancy, or through insurance, both of which have inherent costs. As with any business decision, the organization needs to make a decision considering tradeoffs. Traditionally, this has involved the factors of costs and benefits. Society is more and more moving toward even more complex decision-making domains requiring consideration of ecological factors as well as factors of social equity.

Category	Risk	A	B	C	D	E	F
External							
Nature	Natural disaster: flood, earthquake	X	X		X		X
	Plant fire				X		
	Diseases, epidemics		X				X
Political system	War, terrorism	X			X		X
	Labor disputes	X	X		X		X
	Customs and regulations	X	X	X	X		X
Competitor and market	Price fluctuation			X			
	Economic downturn		X				
	Exchange rate risk	X			X		
	Consumer demand volatility		X	X		X	
	Customer payment	X					
	New technology		X	X			
	Changes in competitive advantage			X			
	Obsolescence	X			X		
	Substitution alternatives				X		
Internal							
Available capacity	Capacity cost	X	X				
	Financial capacity/insurance		X	X			
	Ability to increase production	X		X	X		
	Structural capacity		X	X	X		
	Supplier bankruptcy				X		
Internal operation	Forecast inaccuracy	X	X		X		
	Safety (worker accidents)		X				X
	Bullwhip effect	X		X			
	Agility/flexibility		X	X	X		
	Holding cost/order fulfillment tradeoff	X			X		
	On-time delivery		X		X		
	Quality		X		X		
Information system	IS breakdown	X					
	Distorted information				X		X
	Integration	X			X		X
	Viruses/bugs/hackers		X		X		X

Table I.
Supply chain risk categories

Notes: A – Chopra and Sodhi (2004); B – Wu *et al.* (2006); C – Cucchiella and Gastaldi (2006); D – Blackhurst *et al.* (2008); E – Manuj and Mentzer (2008); F – Wagner and Bode (2008)

Dealing with other external risks involves more opportunities to control risk sources. Some supply chains in the past have had influence on political systems. Arms firms like that of Alfred Nobel come to mind, as well as petroleum businesses, both of which have been accused of controlling political decisions. While most supply chain entities are not expected to be able to control political risks to include wars and regulations, they do have the ability to create environments leading to labor unrest. Supply chain organizations have even greater expected influence over economic factors. While they are not expected to be able to control exchange rates, the benefit of monopolies or cartels is their ability to influence price. Business organizations also are responsible to develop technologies providing competitive advantage, and to develop product portfolios in dynamic markets with product life cycles. The risks arise from competitors' abilities in never-ending competition.

Internal risk management is more directly the responsibility of the supply chain organization and its participants. Any business organization is responsible to manage financial, production, and structural capacities. They are responsible for programs to provide adequate workplace safety, which has proven to be cost-beneficial to organizations as well as fulfilling social responsibilities. Within supply chains, there is need to coordinate activities with vendors, and to some degree with customers (through bar-code cash register information providing instantaneous indication of demand). Information systems technology provides a new era of effective tools to keep on top of supply chain information exchange. Another factor of great importance is the responsibility of supply chain core organizations to manage risks inherent in the tradeoff between wider participation made possible through internet connections (providing a larger set of potential suppliers leading to lower costs) with the reliability provided by long-term relationships with a smaller set of suppliers that have proven to be reliable.

5. Process

A process is a means to implement a risk management plan. Cucchiella and Gastaldi (2006) outline a supply chain risk management process:

(1) Analysis: examine supply chain structure, appropriate performance measures, and responsibilities.

(2) Identify sources of uncertainty: focus on most important.

(3) Examine risks: select risks in controllable sources of uncertainty.

(4) Manage risk: develop strategies.

(5) Individualize most adequate real option: select strategies for each risk.

(6) Implement: this can be combined with a generic risk management process as that provided by Hallikas *et al.* (2004), Khan and Burnes (2007), Autry and Bobbitt (2008), and by Manuj and Mentzer (2008).

(7) Risk identification:

- perceiving hazards, identifying failures, recognizing adverse consequences; and
- security preparation and planning.

(8) Risk assessment (estimation) and evaluation:

- describing and quantifying risk, estimating probabilities; and
- estimating risk significance, acceptability of risk acceptance, cost/benefit analysis.

(9) Selection of appropriate risk management strategy.

(10) Implementation:
- security-related partnerships; and
- organizational adaptation.

(11) Risk monitoring/mitigation:
- communication and information technology security.

Both of these views match the Kleindorfer and Saad (2005) risk management framework of:

- the initial requirement is to specify the nature of underlying hazards leading to risks;
- risk needs to be quantified through disciplined risk assessment, to include establishing the linkages that trigger risks;
- to manage risk effectively, approaches must fit the needs of the decision environment; and
- appropriate management policies and actions must be integrating with on-going risk assessment and coordination.

In order to specify, assess and mitigate risks, Kleindorfer and Saad proposed ten principles derived from industrial and supply chain literatures:

(1) before expecting other supply chain members to control risk, the core activity must do so internally;

(2) diversification reduces risk – in supply chain contexts, this can include facility locations, sourcing options, logistics, and operational modes;

(3) robustness to disruption risks is determined by the weakest link;

(4) prevention is better than cure – loss avoidance and preemption are preferable to fixing problems after the fact;

(5) leanness and efficiency can lead to increased vulnerability;

(6) backup systems, contingency plans, and maintaining slack can increase the ability to manage risk;

(7) collaborative information sharing and best practices are needed to identify vulnerabilities in the supply chain;

(8) linking risk assessment and quantification with risk management options is crucial to understand potential for harm and to evaluate prudent mitigation;

(9) modularity of process and product designs as well as other aspects of agility and flexibility can provide leverage to reduce risks, especially those involving raw material availability and component supply; and

(10) total quality management principles such as Six-Sigma give leverage in achieving greater supply chain security and reduction of disruptive risks as well as reducing operating costs.

6. Mitigation strategies

There are many means available to control risks within supply chains. A fundamental strategy would be to try to do a great job in the fundamental supply chain performance measures of consistent fulfillment of orders, delivery dependability, and customer satisfaction. That basically amounts to doing a good job at what you do. Of course, many effective organizations have failed when faced with changing markets or catastrophic risks outlined in the last section as external risks. Some strategies proposed for supply chains are reviewed in Table II.

Chopra and Sodhi (2004) developed a matrix to compare relative advantages or disadvantages of each strategy with respect to types of risks. Adding capacity would be expected to reduce risk of needing more capacity of course, and also decrease risk of procurement and inventory problems, but increases the risk of delay. Adding inventory is very beneficial in reducing risk of delays, and reduces risk of disruption, procurement, and capacity, but incurs much greater risk of inventory-related risks such as out-dating, spoilage, carrying costs, etc. Having redundant suppliers is expected to be very effective at dealing with disruptions, and also can reduce procurement and inventory risk, but can increase the risk of excess capacity. Other strategies had no negative expected risk impacts (increasing responsiveness, increasing flexibility, aggregating demand, increasing capability, or increasing customer accounts), but could have negative cost implications.

Tang (2006) emphasized robustness. He gave nine robust supply chain strategies, some of which were included in Table III. He elaborated on the expected benefits of each strategy, both for normal operations as well as in dealing with major disruptions, outlined in Table III, organized by purpose.

Chopra and Sodhi (2004)	Tang (2006)	Khan and Burnes (2007)	Wagner and Bode (2008)	Manuj and Mentzer (2008)
Add capacity	Make and buy revenue management			Expand where you have competitive advantage
Add inventory	Strategic stock	Buffers		
Redundant suppliers		Multiple sources	Monitor suppliers	Drop troublesome suppliers
Increase responsiveness		Information sharing	Contingency planning	
Increase flexibility	Product postponement	Product differentiation	Late product differentiation	Delay resource commitment
Pool demand	Flexible supply base			
Increase capability				Outsource low probability demand
More customers				
		Early supplier involvement	Information sharing	Sharing/transfer
		Risk taking	Insurance	Hedge (insure, disperse globally)
				Drop troublesome customers

Table II.
Supply chain mitigation strategies

Strategy	Purpose	Normal benefits	Disruption benefits
Strategic stock	Product availability	Better supply management	Quick response
Economic supply incentives	Product availability	Better supply management	Can quickly adjust order quantities
Postponement	Product flexibility	Better supply management	Can change product configurations quickly in response to actual demand
Flexible supply base	Supply flexibility	Better supply management	Can shift production among suppliers quickly
Make-and-buy	Supply flexibility	Better supply management	Can shift production in-house or outsource
Flexible transportation	Transportation flexibility	Better supply management	Can switch among modes as needed
Revenue management	Control product demand	Better demand management	Influence customer selection as needed
Dynamic assortment planning	Control product demand	Better demand management	Can influence product demand quickly
Silent product rollover	Control product exposure	Better manage both supply and demand	Quickly affect demand

Table III.
Tang's robust supply chain strategies

Cucchiella and Gastaldi (2006) gave similar strategies, with sources of supply chain research that investigated each. Cucchiella and Gastaldi expanded Tang's list to include expansion of capacity. Ritchie and Brindley (2007) included risk insurance, information sharing, and relationship development.

7. Supply chain risk in China

There have been many recent discussions on supply chain risks in China. This has been motivatived by both rapid economic growth and events such as the recent financial crisis, tainted milk scandal, contaminated pet food, contaminated heparin and earthquakes.

China has achieved great economic success in a short period of time. China has experienced around 10 percent GDP growth in the past decade. It has become the global manufacturing center and the winner of most IT outsourcing contracts from developed Asian countries such as Japan and South Korea. A survey from the US Department of Commerce and the International Trade Commission suggests that US-China trade increased nearly fivefold from 1995 to 2005, rising from $57.5 to 285.3 billion. China's global trade increased from $280.9 billion to 1.4 trillion from 1995 to 2005. As a result, China's importance in the global supply chain has grown tremendously. As the economy continues to grow, supply chain risk management has become a business practice that no company can afford to ignore.

To identify and manage supply chain risks in China, we can also categorized emergencies and crises into three categories as what we discussed in Section 1, i.e. natural disasters, malicious activities, and unexpected consequences arising from overly complex systems. Natural disaster event examples include the significant Wechuan Earthquake earlier last year where several factories were destroyed and

supply chains associated with those factories were also destroyed. Malicious activities include the latest tainted milk scandal where the scope of the recall continues to widen. An example for unexpected consequences arising from overly complex systems is the extremely strict limits set by the government regarding factories and on transportation in and around Beijing in order to reduce air pollution during the Beijing Olympics.

The financial crisis has spread all over the world and has begun to affect the economy in China. This trend has also created operating difficulties for many Chinese companies. China must engage in cross-border collaboration in order to succeed in the global marketplace. When facing with changing markets or catastrophic risks in China, many strategies from Section 5 can be used to effectively mitigate various risks. Using the global supply chain is a primary instrument for this cooperation, where Chinese suppliers and vendors will benefit a great deal (Jhangiani, 2007). Technological advances on a global scale will enable them to have financial information about importers, pre- and post-shipment funding sources, and competitive intelligence to a degree previously unavailable. Strategies such as information sharing and pooling demand, increased flexibility and capability can be employed to improve end-to-end transparency leading to more efficient risk management (Wu and Olson, 2007).

8. Conclusions

Ritchie and Brindley (2007) provided a useful framework consisting of five major components to manage supply chain risk. First, look at the context and what drives the supply chain system being studied. Second look at the impact of adverse risk events on organization members. Third, consider the degree of risk aversion. Fourth, identify specific risks and their measures, and develop mitigation strategies. This includes identifying which risks the organization feels competent in dealing with, and which risks they would prefer to insure against or outsource to others. Fifth, monitor key performance outcomes.

We have briefly reviewed recently published supply chain risk cases and models. More detailed analysis of supply chain risks led to their categorization by type. We then considered risk management process, based on a number of recent studies. Finally, mitigation strategies were considered.

Supply chains are critical to contemporary business, and supply chain risk management is crucial. Many recent supply chain events have occurred in China, which is growing in importance with respect to international trade. Specific supply chain risk factors in China were presented.

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