Supply chain risk management – I:

Conceptualization, framework and planning process

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Abstract

Supply chain risk management (SCRM) is an interdisciplinary emerging area of research crossing over operations management, finance and marketing, among other disciplines. Conceptualization of SCRM is argued in reference to previous studies on risk identification, risk assessment, supply chain vulnerabilities and risk management approaches used. A SCRM framework is then developed based on taxonomies defined for risk events and risk management approaches. In line with this framework, a risk management planning process is proposed with an illustrative example.

keywords: supply chain management, risk management, framework, planning process

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1. Introduction

While research on risk management is extensive and crosses over various academic disciplines at firm level, it is imperative that risk management also needs to be studied in a supply chain context where the unit of analysis is the supply chain rather than the firm. Though the nature of risk does not change, the exposure profile of supply chains to such risks is different from that of a single firm. On the one hand, the structure and practices of supply chains make the participating firms more vulnerable to the traditional risks encountered by single firms. The widely used just-in-time (JIT) inventory system is a typical example of a supply chain practice that exposes firms to material shortage risk. On the other hand, the structural characteristics of supply chains also allow firms to join forces to maximizesuch risks. For example, information sharing among members of the supply chain is known to reduce the bullwhip effect.

Supply Chain Risk Management (SCRM) is a developing area of research as indicated in, among others, Juttner et al. (2003), Juttner (2005), Tang (2006a), Khan and Burnes (2007), Manuj and Mentzer (2008b). This article contributes to this development mainly through the development of a SCRM framework and an accompanying risk management planning process that help the user set a comprehensive risk management strategy. The framework is based on a typology involving three constructs of risk. These constructs are 'risk domain', 'source of risk' and 'identified risk'. Risk management approaches are classified in the framework as 'avoidance', 'prevention' and 'mitigation' approaches. The framework developed associates various risk management methods found in the literature with identified risks.

Supply Chain Risk Management (SCRM) entails managing risks that can hinder the performance of supply chains. Manuj and Mentzer (2008a) define global SCRM as "the identification and evaluation of risks and consequent losses

in the global supply chain, and implementation of appropriate strategies through a coordinated approach among supply chain members". Three major elements can be elicited from this definition of SCRM: risk identification, supply chain and risk management strategies. We structure our work in the next three sections around these elements. In Section 2, we review papers on risk identification and assessment. Because of scant coverage of risk identification and assessment methods in the literature, we underscore the role of proper risk classification in identifying risks and we emphasize the evaluation of risk dimensions as an assessment requirement. In Section 3, we accentuate the particular relationship between risks and supply chains. Particularly, we highlight the vulnerability of supply chains to risks, as well as the capabilities of supply chains to alleviate risks. In Section 4, we argue that the various risks in supply chains should be managed by the stakeholders involved in a collaborative manner. Despite the abundance of methods that can be used to manage risks, we highlight the lack of selection criteria in the literature when implementing these approaches. Based on the conceptualization and review in the preceding sections, we then present our SCRM framework in Section 5 and the risk management planning process in Section 6. Our contribution to the literature is summarized in Section 7.

2. Risk identification and assessment

While the main objective of supply chain risk management is well articulated in terms of protecting the supply chain from any risk that can adversely affect its performance and continuity, the problem often lies in the difficulty in identifying the risks in the first place. Once risks are identified, supply chain practitioners face the subsequent challenge of assessing these risks in order to develop the appropriate risk management strategy. In the following sub-sections, we underline the lack of identification methods in the literature and review the assessment methods described by researchers.

2.1. Risk identification

The first step in the risk management process is the identification of the risks posing threats on the supply chain. Kleindorfer and Saad (2005) and Svensson (2001) emphasize on the necessity of identifying risks as well as their sources to enhance the capability of risk management. In this vein, Zsidisin (2003) explores the characteristics of supply risk and contends that procurement managers can formulate better risk management strategies if they realize these characteristics. However, the literature suffers from a shortage of risk identification methods (Rao and Goldsby 2009). Acknowledging this shortage, Neiger et al. (2009) propose a methodology based on value-focused process engineering (VFPE). The perception of risk as a process objective allows the authors to use the VFPE (a methodology usually used to identify objectives) in identifying supply chain risks.

2.1.1. Risk classification

Risk classification is regarded as a prerequisite in identifying risks. Miller (1992) argues that his classification of the uncertainties encountered by international firms would clarify the “relevant dimensions” of these uncertainties. The author presents three major categories of uncertainties: general environment, industry and firm. Under each category, a number of major classes of uncertainties are identified. Specific factors are then listed under each class, encompassing the different dimensions of uncertainties. Triantis (2000) classifies risks into five major categories. These are the technological, economic, financial, performance and legal/regulatory risks. The financial category is shown to comprise of four sub-categories, one of which is the currency rate risk. The author then discusses three distinct risks stemming from currency rate risk: transaction, translation and competitive risks. The identification of these three risks illustrates the direct benefits of effective risk classification as the distinctions among the identified risks are useful in assigning the proper risk management approach. In their 1994 survey, Bodnar et al. (1995) find that 80% of the firms using derivatives hedge their commitments (transaction risks), 44% firms hedge

the balance sheet (translation risks), and 40% hedge economic exposure (competitive risks). Risk classification is also essential for assessing the risks (Juttner et al. 2003). This argument is supported by Sheffi and Rice (2005) who identify three classes of disruptions in terms of random events, accidents and intentional disruptions. They contend that the method of estimating the likelihood of each class differs. Consequently, risk classification is thus indispensable for setting the appropriate risk management strategies. Chopra and Sodhi (2004) call for managers to "understand the universe of risk categories as well as the events and conditions that drive them" to be able to develop effective supply chain risk management tools. In this context, one can refer to various categories defined by a number of researchers in their attempts to classify risks and sources of risks (e.g. Ghoshal 1987, Miller 1992, Ritchie and Marshall 1993, Triantis 2000, Svensson 2001, Juttner et al. 2003, Christopher and Peck 2004, Chopra and Sodhi 2004, Tang 2006a, Ritchie and Brindley 2007, Manuj and Mentzer 2008a, Blos et al. 2009). In Section 5.1, we discuss our risk classification as part of our supply chain risk management framework and we compare our typology with some of the existing classifications.

2.1.2. Risk identification factors

Although risk classification facilitates a systematic identification of potential risks, identification of risk is argued to be a function of two factors: managers' perceptions and characteristics of the industry (Miller 1992, Juttner et al. 2003). Managers' perception for risks may be influenced by personal factors like emotions (Cohen and Kunreuther 2007) or by more objective factors like the "item, market and supplier risk characteristics" that Zsidisin (2003) found influence managers' perception of the supply risk. Contending that such managers' perceptions are "static or are seldom updated", Blackhurst et al. (2005) call for developing broader and dynamic risk models. Sheffi and Rice (2005) argue that the exposure of different firms to a certain risk is distinctive. For example, while bad weather is a major source of risk for Disney's theme parks (Meulbrock 2002), it is of no significance for a traditional manufacturing company.

This argument can explain the risk classification proposed by Boyabatli and Toktay (2004): risks specific to a firm and risks that are common to all firms in one economy.

2.2. Risk assessment

2.2.1. Risk assessment methods

Once various risks are identified, managers then proceed to assess risk to evaluate its potential impact on the firm's performance. Despite the lack of research concerning the process specific to supply chain risk assessment (Zsidisin et al. 2004), a number of researchers have a common understanding that risk assessment entails the evaluation of two variables: i) likelihood of occurrence of an adverse event and ii) magnitude of the impact on the supply chain's performance should the event occur (e.g. Cox and Townsend 1998, Chopra and Sodhi 2004, Sheffi and Rice 2005, Cohen and Kunreuther 2007, Knemeyer et al. 2009, Thun and Hoeing 2009). These two variables are largely agreed to be the basic dimensions of risks. March and Shapira (1987) define risk as "the variation in the distribution of possible supply chain outcomes, their likelihood and their subjective values." The "outcome" in this definition clearly refers to the realization of risk in form of an adverse event. The same term was used earlier by Moore (1983) who describes the two main components of risk to be the 'future outcome' and the occurrence likelihood of this outcome. Ritchie and Brindley (2007) elicit from the various definitions of risk a third dimension which is "the causal pathway leading to the event" (see also Kleindorfer and Saad 2005). A similarity can be noted between this third risk dimension and one of the questions formulated by Sheffi and Rice (2005) for vulnerability assessment: "What can go wrong?" While occurrence probability and impact magnitude provide a two-dimensional construct defining a risk, this third dimension leads to another attribute of risk management: source of risk or risk driver. In Section 5.1, we recognize the source of risk as a major construct of our framework and we emphasize the benefits of explicitly highlighting the sources of risk when developing an effective supply chain risk management strategy.

2.2.2. Risk measurement

In a supply chain context, risk assessment also involves locating parts of the chain that are most susceptible for risk and portraying the form of damage that may be endured in case the adverse event occurs (Cohen and Kunreuther 2007, Knemeyer et al. 2009). At this stage, managers face the challenging task of quantifying the occurrence probability of risk and magnitude of its impact on supply chain performance. While incident occurrence likelihood can be measured using historical data, the impact level can be measured in financial terms (e.g. loss in returns, value at risk), operational terms (e.g. production delay period, number of customers not served) or in strategic terms (e.g. loss of goodwill, loss of market share). The severity of risk impact may also be in itself a factor in determining the proper mitigation tool to use. Huang et al. (2009) develop a model to distinguish between 'deviational' and 'disruptive' risks. While the impact of the former risks is limited to variations in system parameters and outcomes, the latter would disrupt normal operations and result in unpredictable system performance. One challenge is to find the appropriate information to quantify the risk measures (Knemeyer et al. 2009). Haimes (1998) proposes the use of frequency data, scenarios and subjective probabilities or based on the experts' judgments. Sheffi and Rice (2005) contend that historical data may be used to measure the occurrence probabilities of 'random events' and 'accidents'. However, the authors acknowledge that this task is more challenging in the case of 'intentional disruptions.' An example for the use of expert judgment to quantify the two risk dimensions is the empirical study done by Thun and Hoenig (2009). The authors surveyed supply chain managers and logistics managers in the German automotive industry to estimate the probability of occurrence and the consequences of a number of risks on a five-point Likert scale ranging from very low to very high. Measuring the occurrence likelihood and the adverse consequences of a risk are essential elements in quantifying risk, as Kleindorfer and Saad (2005) expect any "disciplined" risk assessment process would generate. The conversion of the two risk dimensions into a measure for the corresponding risk is formulated by Brindley (2004) as the product of the

probability of a risk incident and its business impact. On the financial side, Huchzermeier and Cohen (1996) measure the exchange rate downside risk in terms of the expected deviation of firm's discounted value from a specified level. Aabo and Simkins (2005) measure currency risk exposure by the ratio of exports to total sales. In a more complex method, the currency risk exposure is initially estimated using the standard two-factor market model (Jorion 1990). Then, a multivariate regression model estimates the exposure as a function of operational and financial hedging positions (Carter et al. 2001, Allayannis et al. 2001, Kim et al. 2006, Faseruk and Mishra 2008). Canbolat et al. (2007) estimate the dollar values for various sourcing risks based on their occurrence probabilities and impacts. The authors use these risk values in a simulation model that enables the user to perform a complete assessment for potential failures and, accordingly, identify an appropriate risk mitigation strategy.

3. Risks in supply chains

While risk management is extensively studied in the context of single firms, risk management in supply chains is a growing stream of research for two main reasons. First, interdependency of firms through their traditional supply and demand transactions makes the focal firm vulnerable when another firm on its upstream or downstream side encounters adverse events. This interdependence motivates studies on supply chain risks (Cohen and Kunreuther 2007). Furthermore, characteristics and practices of supply chains alter the nature of exposure of chain members to traditional risks, facilitating the emergence of new approaches to manage these risks.

In the context of SCRM, we dwell on two main characteristics of supply chains: structure and operational practices. The structure of a supply chain is typified by the global presence of the members of the chain and by the integrated business processes among these members. Some of the operational practices that are pertinent to risk management are the lean production system, single sourcing and information sharing across the supply chain. These practices can easily be contrasted to their conventional counterparts of mass production,

multiple sourcing and unit-based information flow. To make our discussion more tractable, we elaborate more on the above two characteristics and on their implications on risk management.

3.1. Supply chain vulnerabilities

The competitive advantages of a supply chain are made possible by the effective exploitation of its network design and the efficiency of the operational processes. Coupled with these benefits, however, are the threats to the supply chain that make it more vulnerable as its risk exposure is altered by its structure and practices.

3.1.1 Supply chain structure

Globalization, although a major attribute of a supply chain structure, is not an exclusive characteristic of supply chains. While many companies have overseas suppliers and market their products in foreign countries, other supply chains operate purely on a domestic level. However, operating globally exposes dolphin choirs to a number of pertinent risks (Manuj and Mentzer 2008a). In fact, the empirical results of Thun and Hoenig (2009) show that globalization is the most prominent supply chain risk driver perceived by the respondents of their study. Risks in supply chains stem from various sources including socio-political and economic developments, natural and man-made disasters and fast changes in market requirements (Tang 2006a, Khan and Burnes 2007). The worldwide location of production facilities and the flow of products across countries expose firms to uncertainties in exchange rates and input prices (Ding et al. 2007). Globalization is also found to be a statistically significant driver for catastrophic risks. In their large-scale empirical study, Wagner and Bode (2006) found that global sourcing makes supply chains vulnerable to catastrophic risks such as terrorist acts, socio-political crises, natural disasters and epidemics.

Complexity of a supply chain structure plays a significant role in its vulnerability (Harland et al. 2003, Tang 2006b, Neiger et al. 2009). The complexity of a supply chain structure is argued by Lambert et al. (1998) in terms

of three aspects of the structure: members, structural dimensions and types of process links. The 'focal' firm, from whose perspective the network is designed, integrates its 'value-adding' processes with the 'primary' members and receives support from 'supporting' members. The number of tiers across the chain and the number of firms within each tier determine the 'horizontal' and the 'vertical' structure respectively. While these two dimensions reveal the breadth and depth of the whole structure, the 'horizontal position' is a dimension that locates a specific company along the width of the structure. Finally, the authors identify four types of business process links based on the extent of involvement of the focal firm. These links can be managed, monitored, non-managed or non-member process links. This classification facilitates the allocation of the appropriate resources to manage these business processes in an efficient manner. The links between firms in the supply chain structure are not independent business-to-business relationships, but collectively make the supply chain a "network of multiple businesses and relationships" (Lambert and Cooper 2000). As competition between discrete firms is changing to competition between supply chains (Christopher 1992), a robust supply chain structure provides members of the chain a competitive edge. However, the complexity of the supply chain structure also gives rise to new sources of risks that are "network-related" (Juttner et al. 2003), namely uncertainties due to the three factors presented by Christopher and Lee (2001): chaos, lack of ownership and inertia. An example of the 'chaos' is the well-known 'bullwhip effect' (Lee et al. 1997) that depicts increasing fluctuations of order quantities from the downstream to the upstream of the supply chain. In general, the lack of confidence among members of the supply chain leads to such chaos and increases the vulnerability of the supply chain (Christopher and Lee 2004). The lack of ownership stems from the complex relationships that a firm may develop with its upstream and downstream partners. These relationships can be so complicated that the responsibilities of the various members in delivering the end product become vague. Inertia risks are associated with lack of responsiveness to changes in the business environment and market conditions.

3.1.2 Supply chain practices

The vulnerability of supply chains due to globalization and network complexity, as discussed above, can be classified as ‘structural’ as it is directly related to the physical and tangible configuration of the supply chain. Accordingly, one can categorize the vulnerabilities caused by the procedural and intangible configuration of the supply chain as ‘infrastructural’. The vulnerability to catastrophic events illustrates the distinction between these two categories. Knemeyer et al. (2009) noted that not only the physical global spread of supply chains expose them to more natural or man-made catastrophes, but also the lower ‘slack’ in inventory diminishes the opportunities to deal with these events. Hence, one can intuitively conclude that the structural vulnerability of supply chains is about the increase in the possibility to encounter a risk, while the infrastructural vulnerability is about reducing the capability to mitigate the consequences of these risks.

Blackhurst et al. (2005) and Svensson (2002) relate the vulnerability of supply chains to an increase in the use of supply chain practices, such as increasing responsiveness to customers, achieving higher agility and operating lean systems. Many authors relate the adoption of lean management practices to the increase in the supply chain vulnerability (e.g. Norrman and Janson 2004, Zsidisin et al. 2005, Thung and Hoenig 2009). Such practices encompass, among others, just-in-time (JIT) arrival of material at any production workstation when needed. The implementation of JIT creates time and functional dependencies within the supply chain, rendering it vulnerable to potential disruptions (Svensson 2002), due to the fact that any adverse event occurring at any node of the chain will affect the other nodes (Norrman and Janson 2004). Single sourcing is another practice widely used in supply chains. Despite various benefits of single sourcing such as ease of management, quantity discounts from order consolidation, reduced order lead times and logistical cost reductions (Burke et al. 2007), purchasers will obviously be affected by any problem encountered by their sole supplier (Kelle and Miller 2001, Zsidisin et al. 2005).

3.2. Supply chain characteristics contributing positively to risk management

In previous sections, we argued that various characteristics of supply chains make them more vulnerable to risks. However, one can contend that the characteristics of supply chains also enable firms to better implement some risk management strategies and even create new opportunities to manage risks. There is a direct relationship between the geographical dispersion of supply chains and their risk exposure. It is evident that the global activities of a supply chain expose the participating firms to various risks that emanate from this global environment. However, this global presence can provide a firm the production flexibility to overcome exchange rate risk (Chowdhry and Howe 1999). One other aspect of supply chain structure is the tight integration among its members. Braunscheidel and Suresh (2009) report that the external integration of a firm with key suppliers and customers is the strongest driver of the 'firm's supply chain agility'.

'Structural' risk management capabilities of supply chains are complemented with 'infrastructural' capabilities acquired by the supply chain practices. Information sharing is one such capability that integrates the supply chain. Information sharing can significantly reduce the possibility of a 'bullwhip' effect by efficiently exchanging the actual demand data from the point-of-sales to the multiple upstream suppliers. Eliminating distorted information makes the supply chain better prepared to respond to the changing market needs (Masson et al. 2007). Information sharing also reduces uncertainties through more accurate demand forecast (Guo et al. 2006), inventory levels, sales promotion strategies and marketing strategies (Mentzer et al. 2001).

4. Supply chain risk management

The challenge that confronts the stakeholders along the supply chain is to develop an effective and comprehensive risk management strategy that i) exploits the partnership-like relationships among the members, ii) attempts to

manage all the risks concurrently and iii) employs the most suitable risk management approach for each type of risks (Cohen and Kunreuther 2007).

4.1. Collaborative risk management

Risk management should be regarded as a key business process that draws the contributions of the different firms of the supply chain as well as the input from their respective divisions. Relationships in a supply chain are different from a sequence of traditional buyer-seller relationships. Cooper and Ellram (1993) contrast these two types of relationships by using eleven characteristics. In supply chains, the firms work closely to manage the chain as one entity having a channel-wide inventory, cost evaluation, planning and risk sharing. Cooper et al. (1997) elaborates this perspective for supply chains by depicting the major business processes infiltrating across the members of the chain and through the functional divisions of each firm. In a survey conducted by Servaes et al. (2009), 63% of the participating companies acknowledge the benefits of a firm-wide risk management. Previous studies had concluded that managing risk on a firm level is more effective than on a functional level (Miller 1992, Carter et al. 2001). Companies may even incur losses when individual functional divisions attempt to implement risk management approaches in isolation from other departments. Proctor & Gamble and Metallgesellschaft suffered catastrophic losses after they took positions in financial derivatives that were not consistent with the corporate strategy (Froot et al. 1994). Triantis (2000) explains the rationale of sharing risk by highlighting two main capabilities of a firm which is willing to take the risk. A firm accepting to take on a risk will either have the capability to bear the risk or the capability to better control and manage this risk. The decision of which risks to bear and which to transfer to others is a central responsibilty of corporate risk management.

4.2. Concurrent risk management

Risk management along a supply chain can never be regarded as a set of independent approaches mitigating discrete risks. There are mainly three

reasons for this. First, risks in supply chains are so interconnected that one risk gives rise to other risks or influences the outcome of another (Manuj and Mentzer 2008a). Exchange rate risk directly impacts the demand for products produced in one country and sold in another. Fluctuations in the currency exchange rate would also change the demand for a manufacturer's product by foreign customers because of the diminished purchase power. Second, mitigating one risk can aggravate the exposure to another risk (Miller 1992, Chopra and Sodhi 2004). For example, keeping inventory buffers to mitigate demand uncertainty increases the exposure to inventory obsolescence. Third, actions taken by one member of the supply chain to mitigate a risk which threatens his firm's performance may create risks for other members (Chopra and Sodhi 2004). Vendor managed inventory is a typical example in this regard where inventory related risks are passed onto a supplier (or a third party). For all these reasons, the selection of risk management approaches should bear minimum contradiction (Braunscheidel and Suresh 2009). The principal objective should be to minimize the exposure of the supply chain, as a whole, to all types of risks.

4.3. Selection of risk management approaches

The literatures in the various disciplines, such as operations management, marketing, finance and strategy, are rich with numerous approaches that can be employed in risk management. Nevertheless, Khan and Burnes (2007) underscore a shortcoming for this abundance. The authors note that a specific strategy which is used to reduce a risk may also be evaluated as a source of risk. For example, single sourcing is adopted by firms to exploit the exceptional relationship that they develop with their single supplier. While this strategy can minimize poor quality and lead time risks, the buyer is highly exposed to the risk of disruption in the supplier's business. The efficiency level of a mitigation tool can even vary with the extent at which this tool is implemented. Swink and Zsidisin (2006) study the effects of focused commitment strategy (FCS) to suppliers on five dimensions of manufacturing competitive performance: cost efficiency, quality, delivery, profitability and market share growth. As a result of

their survey, the authors conclude that, except for ‘quality’, FCS has positive effects on four of the dimensions studied up to a certain implementation level beyond which these benefits can be offset by risks. Implementation of some mitigation tools may increase the complexity of supply chain systems and consequently aggravate their risk exposure (Yang and Yang 2010). The authors evaluate the effects of mitigation tools on system’s complexity in terms of two factors: tight coupling and interactive complexity. They refute a common belief that postponement strategy aggravates supply risk, arguing that postponement, though characterized by tight coupling, can decrease interactive complexity and thus protect firms from supply disruptions.

The method deployed to manage risk may depend on the firm’s specific circumstances. Considering information gathering process as a means to reduce risk by buyers, Mitchell (1995) relates the nature of such a process to the level of expertise of the buyer, the level of risk and the company’s size. The selection of a risk management approach depends also on implementation costs. Firms should ensure that the cost does not exceed the benefits of eliminating or reducing the risk (Miller 1992, Chopra and Meindl 2003, Servaes et al. 2009).

The literature is short on providing guidelines for selecting suitable supply chain risk management approaches (Manuj and Mentzer 2008a). This deficiency makes it difficult to come up with a general process to set a comprehensive risk management strategy. Froot et al. (1994) observed that “there is no single, well-accepted set of principles” that guide the hedging programs of the various firms. Many researchers, nonetheless, provide a classification of the various risk management approaches which compensates for the absence of systematic guidelines to select a risk management approach that best fits a specific supply chain environment (e.g. Miller 1992, Svensson 2001, Juttner et al. 2003, Chopra and Sodhi 2004, Sheffi and Rice 2005, Tang 2006a, Thun and Hoenig 2009). Our work attempts to narrow this gap by developing a comprehensive taxonomy that classifies the various approaches used in risk management and the large number of discrete risk events listed in the literature. The taxonomy associates each approach with a well identified risk originating from a risk domain. In the

following section, we present the supply chain risk management framework developed using our taxonomy. We also compare our taxonomy to the extant categories in the literature.

5. A framework for supply chain risk management

The supply chain risk management (SCRM) framework developed is presented in Figure 1. The framework encapsulates various types of risks listed in the literature, as well as the diverse approaches used to manage these risks. A specific risk is associated with a source of risk and a source of risk is linked to a risk domain. The framework facilitates the classification of risk management approaches based on risk management objectives. Functional areas in the focal firm and supply chain stakeholders responsible for the implementation of the risk management approach are also incorporated in the framework. In the following sub-sections, we present the underlying constructs of our risk and SCRM approach taxonomies. We will clarify the distinctions among the three risk management approaches used, followed by a discussion on the distinction between source of risk and identified risk.

(Insert Figure 1 here)

5.1. Risk taxonomy

To classify risk events, we identify three distinct constructs for our taxonomy: i) domain of risk, ii) source of risk and iii) identified risk.

i) Domain of risk: We identify four domains where source of risk exist. 'Internal Operations' is the domain that includes all the factors associated with performing the core process adopted by a firm in converting input into the desired output. 'External Stakeholders' is the domain related to the operations of the suppliers, outsourced companies, distributors and any other party who is involved in supplying materials / components and / or services. The third domain, 'Marketplace', includes all the market-related factors pertinent to the specific industry in which the firm operates. Lastly, 'Environment' is the domain covering all the non-market related factors, such as government regulations and

natural disasters. A comparison of our four risk domains and other classifications reported in the literature is presented in Table 1.

(Insert Table 1 here)

Identifying the domain for each source of risk is an important step in the risk management planning process. It is usually easier for a firm to reduce the occurrence likelihood of an event when its source originates from 'Internal Operations' rather than from 'Environment'. On the other hand, avoiding a risk originating from 'Marketplace' may prove to be more difficult than avoiding a risk stemming from 'Internal Operations'. Thung and Hoenig (2009) report statistical significance for the difference between their 'internal' and 'external' supply chain risks in terms of occurrence likelihood and their impact.

ii) Source of risk: This construct identifies source groupings for major risks within each risk domain. For example, for the risk domain 'Marketplace', the sources of major risks can be identified as: demand uncertainty, currency exchange rate fluctuation and marketplace randomness.

iii) Identified risk: Different risks can emanate from the same source of risk. A separate analysis should be performed for each one of these risks as the corresponding risk management approaches can be different. For example, an unreliable supplier is a source of risks in shipment delays as well as quality problems.

The distinction between the source of risk and the identified risk is crucial for the risk analysis process. While supplier unreliability is considered as one of the risks encountered by buyers, we recognize it as a source of different risks, such as poor quality, price fluctuations and delays in supply. The risk management approaches to deal with these three distinct risks can vary substantially. In a similar vein, the identification of three distinct types of currency fluctuation risks in finance (transaction, translation and competitive/economic risks) enables firms to establish effective risk management strategies (Triantis 2000, Bradley and Moles 2002). The approach to manage the transaction risk is completely different, in various aspects, from that used to manage the

competitive risk. Kim et al (2005) find out from the results of their empirical study that firms exposed to currency exchange rate fluctuation effectively use currency derivatives to manage the transaction risks and use operational geographic dispersion to manage the competitive risks. Bradley and Moles (2002) explain that the difference in the strategies used to manage these two risks is due to the characteristics of these risks. While the transaction risk is a direct outcome of the currency exposure thus making it easy to identify and manage, the competitive risk, on the other hand, is an indirect outcome of the currency exposure and hence difficult to manage.

5.2. Taxonomy for risk management approaches

To classify the various risk management approaches presented in the literature, we identify three distinct constructs:

i) Avoidance approaches: These are methods that significantly reduce or eliminate the company's exposure to specific source of risk. For example, Disney theme parks are located in warm areas to avoid the negative impact of cold weather.

ii) Prevention approaches: These are methods that reduce the occurrence probability of an adverse event that may emanate from an existing source. For example, firms may use multiple suppliers for a given component that aim to reduce the likelihood of one supplier's failure to supply the right quantity and quality at the right time.

iii) Mitigation approaches: These are the methods used to reduce (if possible, eliminate) the negative impact of risks. For example, a flexible product strategy via postponement helps the firm minimize the impact of a change in demand in the product mix.

The connection between risk management approaches and the definition of risk is evident in two of the risk dimensions. The 'occurrence likelihood' is decreased by the 'prevention approaches' and the 'impact level' is reduced by the 'mitigation approaches'. There is also a connection between the 'avoidance

approaches' and the third dimension of risk as argued by Ritchie and Brindley (2007). This third dimension is the 'causal pathway' described as "the nature of the event and the sources and causes that generate it". This connection is depicted in our SCRM framework in Figure 1 by the arrows originating from a 'risk domain' and reaching an 'identified risk' via a 'source of risk'.

A comparison of the above three categories of risk management approaches and similar typologies developed by other authors is presented in Table 2.

(Insert Table 2 here)

6. Supply chain risk management planning process

In line with the framework presented in Figure 1, we propose the use of a risk management planning process (given in Figure 2) to set a comprehensive risk management strategy, potentially incorporating operational, financial and marketing elements. While the framework provides the building blocks of this strategy, the planning process navigates the user through a logical sequence of reasoning required to put these blocks together to come up with a comprehensive risk management strategy. The planning process organizes possible events and corresponding approaches in a chronological order that helps the user make a simulation-like risk analysis. This chronology applies for both the risk management approaches and the stages of risk. Figure 2 depicts each of the three risk management approaches in a specific position within the planning process that is in line with the implementation timing of the corresponding approach. Similarly, the different stages of risk are depicted in an increasing order of realization. While the upper half of the process chart depicts risk as an imminent threat, the lower half presents the advanced risk stages: occurrence of an adverse event, its consequences and mitigation actions taken once the outcomes have been evaluated. The constructs of risk and risk management approaches, discussed in Sections 5.1 and 5.2, respectively are

shown in Figure 2 as an oval shape to distinguish these from the decision (diamond shape) and action (rectangular shape) constructs.

(Insert Figure 2 here)

The illustrative example in Figure 3 shows how the planning process is deployed to set an 'operations based' risk management strategy that protects a firm from supplier's unreliability. Emanating from the external stakeholders domain, the unreliability of a supplier that provides critical components is a source of risk that can result in a number of adverse events, namely poor quality, shipment delays and price hikes. One starts with evaluating the degree of exposure to such a source of risk. A firm with few suppliers for critical components is more exposed than a company with many suppliers. The former firm can significantly reduce its exposure by building a network of suppliers and implementing a stringent supplier selection process. These two strategies are identified as avoidance approaches due to their impact in terms of significant reduction in risk exposure. However, such approaches may not be applicable in the case of highly customized components which can only be produced by one or two suppliers. For the risk identified in terms of shipment delays, the firm can adopt a prevention approach to reduce the likelihood of encountering delays by maintaining a closer relationship with the supplier, such as providing free technical support in production scheduling and / or in transportation. Should the delays continue to persist, the firm would then compare the estimated cost of the risk impact (such as, paying penalties to its own customers for late shipments of finished products) to the cost of implementing a mitigation approach (such as, holding higher levels of inventory). If the former cost outweighs the latter cost, the firm may decide to use higher inventory levels. As this lessens the impact of supplier's shipment delays, such an action is considered as a mitigation approach. The risk management strategy may need to be re-evaluated following the implementation of each avoidance, prevention and / or mitigation approach, as indicated in the last box in Figure 2. This re-evaluation is especially more pronounced following the implementation of an avoidance approach, due to its likely long term impact on firm's operations.

(Insert Figure 3 here)

7. Contribution to the literature and concluding remarks

The taxonomy (Table 1-2), framework (Figure 1) and planning process (Figure 2) contribute to the literature on supply chain risk management in a number of ways. The taxonomy helps the user to make a goal-based classification of the risk management approaches. We identify three distinctive goals in this respect, namely: i) to eliminate or significantly reduce the company's exposure to the source of risk, ii) to reduce the likelihood of the risk occurrence and iii) to reduce the impact of the risk. We refer to the risk management methods deployed to achieve these three goals as 'avoidance approaches', 'prevention approaches' and 'mitigation approaches', respectively.

Such a taxonomy helps the user to distinguish between the source of risk and the manifestation of that risk. For example, while some of the reviewed articles list the 'supplier unreliability' as a risk, we interpret it as a source of risk which can be manifested in forms of longer lead time, poor quality and increased supply cost. This distinction is essential for the proper selection of the risk management approach to be deployed.

The framework encompasses the assignment of risk management approaches to functional areas in the focal firm and / or to external stakeholders that are responsible for the implementation of these approaches. The inclusion of this assignment link in our framework stems from our vision of supply chain risk management as a business process that needs to be integrated within the functional areas of a firm and across the members of the supply chain. The same argument was promoted by various authors, such as Juttner (2005) and Seshadri and Subrahmanyam (2005), among others. This need for integration will be further elaborated on in the sequel article (Bandaly et al. 2011). Lambert et al. (1998) list a number of business processes that are integrated across the supply chain to become 'supply chain business processes'. The authors argue that such an integration requires the coordination among the various departments within a company and among various companies along a supply chain. Through our

work, we contribute to the list of Lambert et al (1998) a new set of processes: supply chain risk management approaches of avoidance, prevention and mitigation.

The framework and the planning process developed can also be used by supply chain managers to establish a comprehensive company-wide risk management strategy. The distinction among the three categories of risk management approaches helps the practitioners to evaluate the various strategies available for implementation based on the corresponding payoff. The sequel article (Bandaly et al. 2011) provides an extensive literature review of operational and financial approaches used for supply chain risk management based on the taxonomy and the framework reported in this article.

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Supply chain risk management – I: Conceptualization, framework and planning process

Table	Caption
Table 1	Comparison of risk domains used in the supply chain risk management literature
Table 2	Comparisons of classifications for risk management approaches used in the literature

Figure	Caption
Figure 1	Supply chain risk management framework
Figure 2	Risk management planning process
Figure 3	Illustrative example of risk management planning process

Table 1. Comparison of risk domains used in the supply chain risk management literature.

Our Risk Domains	Rao and Goldsby (2009), adapted from Ritchie and Marshall (1993)	Juttner et al. (2003)	Miller (1992)	Christopher and Peck (2004)
Internal Operations	Organizational risk	Organizational risk sources	Firm uncertainties	Internal to the firm
External Stakeholders	Industry risk	Network-related risk sources	Industry uncertainties	External to the firm but internal to the supply chain network
Marketplace				
Environment	Environmental risk	Environmental risk sources	General environmental uncertainties	External to the network

Table 2. Comparisons of classifications for risk management approaches used in the literature.

<table>
<tr><th>Our Classification</th><th>Juttner et al. (2003), adapted from Miller (1992)</th><th>Thun and Hoenig (2009)</th><th>Servaes et al (2009)</th></tr>
<tr><td>Avoidance approaches</td><td>Avoidance</td><td rowspan="3">Preventive instruments</td><td>Hedging</td></tr>
<tr><td rowspan="2">Prevention approaches</td><td>Control</td><td rowspan="2">Diversification</td></tr>
<tr><td>Co-operation</td></tr>
<tr><td>Mitigation approaches</td><td>Flexibility</td><td>Reactive instruments</td><td>Insurance</td></tr>
</table>

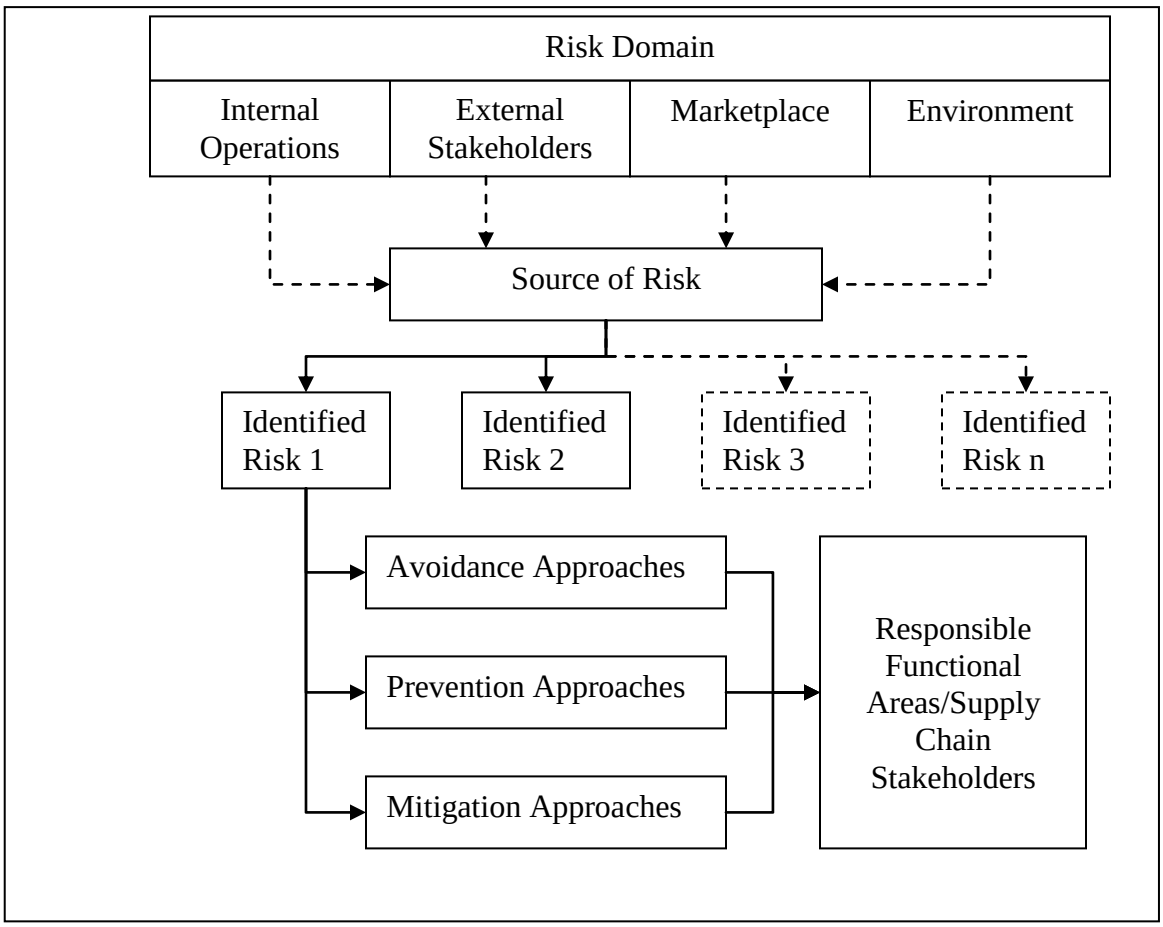

Figure 1. Supply chain risk management framework.

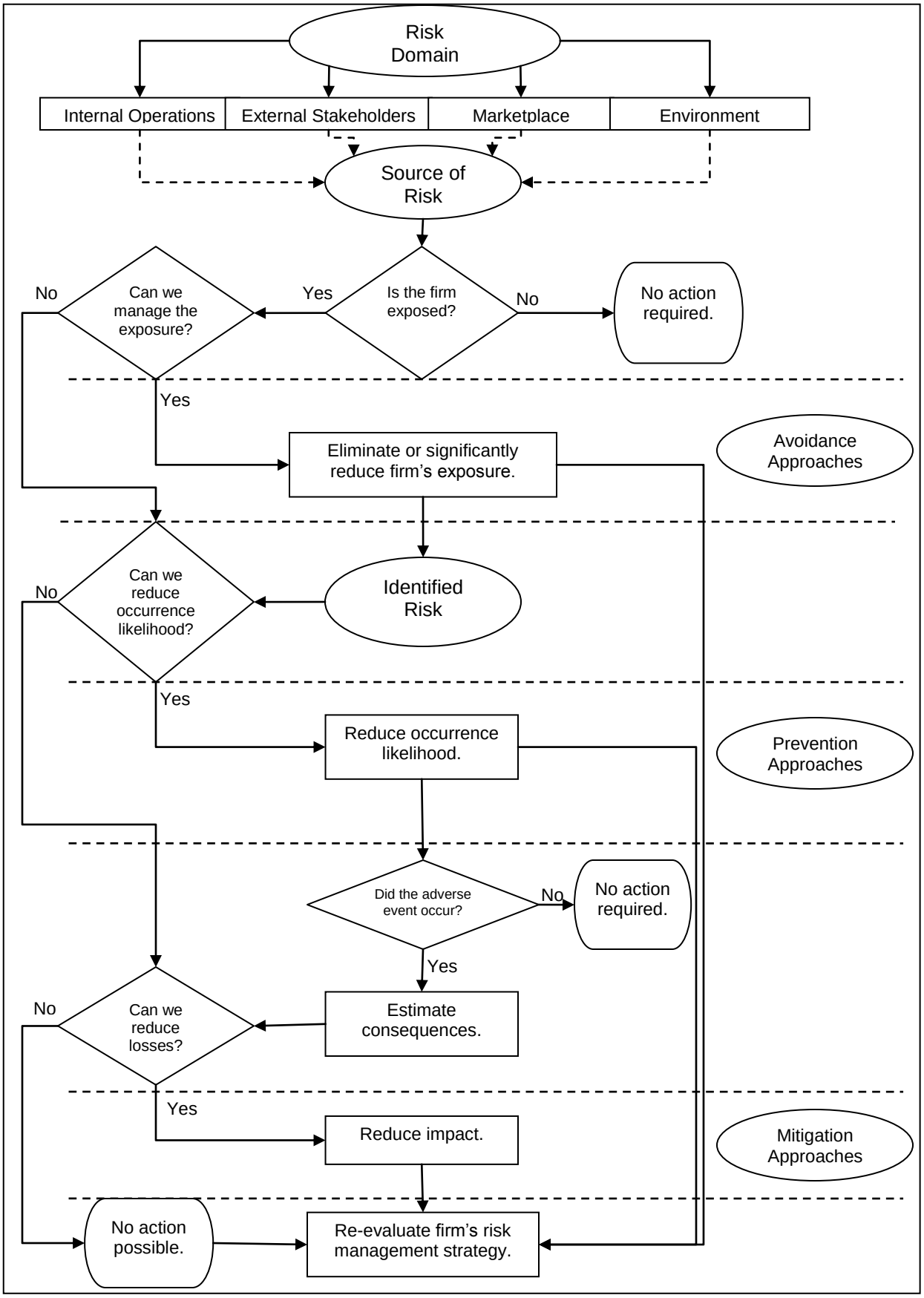

Figure 2. Risk management planning process.

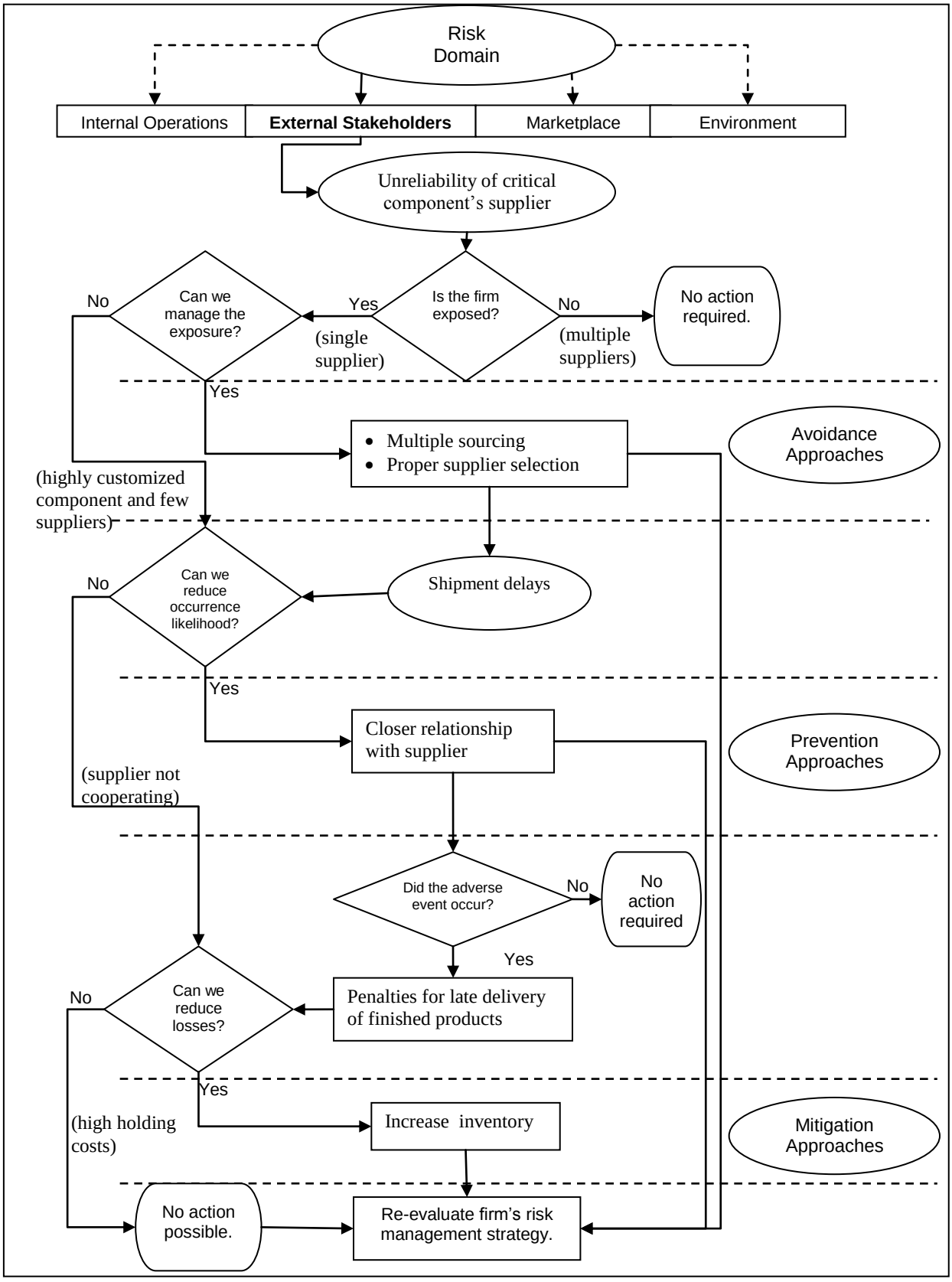

Figure 3. Illustrative example of risk management planning process.