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# The effects of vulnerability mitigation strategies on supply chain effectiveness: risk culture as moderator

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## Abstract

**Purpose** – The vulnerability issue in supply chains is among the most pressing concerns that firms are currently facing. As a preliminary attempt to address the lack of empirical research, this paper aims to primarily explore the relationship between vulnerability mitigation strategies and supply chain effectiveness with security culture as a moderator.

**Design/methodology/approach** – Data are gathered via a survey of 209 Indonesian manufacturing firms. The data are analyzed using partial least squares technique.

**Findings** – Results indicate that supply chain visibility, supply chain flexibility and supplier development strategies positively affect supply chain effectiveness. Moreover, risk culture positively moderates the effects of supply chain visibility and supplier development on supply chain effectiveness.

**Practical implications** – The findings may improve supply chain effectiveness by mitigating the effects of vulnerability causes.

**Originality/value** – This study contributes to the advancement of knowledge on the relationships between vulnerability mitigation strategies and supply chain effectiveness.

**Keywords** Risk management, Effectiveness, Supply chain vulnerability

**Paper type** Research paper

## 1. Introduction

In the present environment, companies operating within highly integrated supply chains find themselves increasingly vulnerable to disruptions caused by natural and man-made disasters. These disruptions are borne out in recent events, such as the 2010 devastating earthquake in Haiti that claimed thousands of victims, the 2011 floods in Thailand with economic costs estimated at US\$450bn and the 2013 typhoon in the Philippines that left massive property destruction in its wake. Risks and uncertainty exist during each stage of activities necessary to acquire products and services to deliver output to customers (Harland *et al.*, 2003; Barros *et al.*, 2013). Unintended or unforeseen disruptions may occur during purchasing, manufacturing or even delivery, which adversely affect the ability of the firm to serve its customers. The effect

of risks and uncertainty must be anticipated by mitigation efforts aimed at maintaining overall business continuity.

At present, supply chain management faces an array of risks that have emerged only in recent years, spurred by twin factors of globalization and rapid development of technology (Ritchie and Brindley, 2004; Scannell *et al.*, 2013). However, supply chain vulnerability is not only the result of turbulent environment but also largely explained by the design of the supply chain itself (Bode and Wagner, 2015). Supply chain managers, therefore, face tremendous challenges in developing appropriate mitigation strategies. In response, researchers are now revisiting the concept of supply chain vulnerability (Enyinda and Szmerekovsky, 2008; Juttner and Maklan, 2011; Ozlen *et al.*, 2013; Zhou and Piamuthu, 2013).

Supply chain development is facing increasingly tough competition and a more vulnerable environment. Aside from traditional risks that arise from business activities, companies face new risks that emerge from sources that are correlated to cooperation with their partners (Giunipero and Eltantawy, 2004;

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Hearnshaw and Wilson, 2013). Companies are often incapable of handling indirect supply chain risks because the origins of these risks are simply out of their visibility horizon. This phenomenon, which is responsible for the increasing supply chains risk, is known as supply chain vulnerability (Kersten et al., 2006). In literature, several factors are repeatedly cited as the drivers of supply chain vulnerability, such as global sourcing, lean management and high dependence on suppliers and customers. Barnes and Oloruntopa (2005) consider that vulnerability is determined by the susceptibility of the existence of organizational design or function to risk. The combination of risk sources and vulnerability drivers leads to an increase in vulnerability to the supply chain (Kersten et al., 2006). The supply chain vulnerabilities can have a significant impact on the effectiveness of the supply chain, and such vulnerabilities occur due to elements which have impacts on both upstream and downstream operations (Chopra and Meindl, 2007). Hendricks and Singhal (2005) showed that supply chain disruptions that have been reported publicly reduced the shareholder value by 8 per cent. To reduce vulnerability severe effects, vulnerability mitigation strategies must be embedded within supply chain development. The arguments that implementation of vulnerability mitigation strategies is costly (Stecke and Kumar, 2009) make it questionable whether implementation of mitigation strategies has a positive effect on supply chain effectiveness. Therefore, further studies on the impacts of supply chain mitigation strategies on supply chain effectiveness are needed.

Numerous researchers have recommended mitigation strategies to improve supply chain effectiveness (Kauffman et al., 2012; Hatani et al., 2013). To the best of our knowledge, the effectiveness of such suggested mitigation strategies in enhancing the supply chain effectiveness has not yet been empirically investigated. Wagner and Neshat (2010) suggest that not every mitigation strategy is effective in reducing supply chain vulnerability. Furthermore, despite its importance, little or no research has been conducted concerning how security culture may affect the relationship between vulnerability mitigation strategies and supply chain effectiveness. As a result, little is known about how security culture influences the scope and deployment of vulnerability mitigation strategies and thereby differentiates firm performance. The organizational culture of companies in Asia (including Indonesia) is totally different from companies in other countries (Cullen et al., 2004; Morris et al., 1998). Because of the continuing increase in global competition, an investigation of the role of security culture offers substantial value to practitioners. In addition, an investigation of the role of security culture may refine our conceptual understanding of the linkages between supply chain security practices and effectiveness, especially in the context of developing countries. To fill these gaps, the present study empirically analyzes the effects of vulnerability mitigation strategies on supply chain effectiveness by considering risk management culture as a moderator. The research results contribute to minimizing the effect of vulnerability factors on supply chain effectiveness. The findings provide useful inputs to all manufacturing firms in managing vulnerability risks with proper mitigation strategies.

This paper is organized as follows. After the introduction, a literature review on supply chain effectiveness, vulnerability mitigation strategy and risk management culture is provided.

A conceptual model is then proposed to determine the relationships between vulnerability mitigation strategies and supply chain effectiveness, as well as test the moderating effect of risk management culture. Subsequently, an empirical study is developed to validate the proposed conceptual model. The findings and contributions are discussed afterwards. Finally, the limitations of this study are presented.

## 2. Literature review

### 2.1 Supply chain effectiveness

Supply chain effectiveness represents direct and indirect effects of mitigation strategy adoption. Linking mitigation strategy with supply chain effectiveness is an important measurement related to supply chain performance. The capability requirements to improve operational performance are acquired from the development of effective external and internal relationships (Lee et al., 1997). Effectiveness measurement is required to reflect the result of mitigation strategy adoption. Supply chain effectiveness indicates how well the firm's organization in a supply chain achieves its financial and operational goals (Gunasekaran et al., 2004).

Financial and operational goals are obtained when supply chain operations are capable of balancing cost and effectiveness. Supply chain operation strategy plays a critical role in promoting performance improvement and contributes strategically to overall supply chain effectiveness (Humphreys et al., 2004). Fugate et al. (2009) mention that the effectiveness of supply chain operation can be measured based on its ability to manage transportation, warehousing and inventory costs and total acquisition costs. Supply chain effectiveness includes cost reduction in shipping and handling, as well as lowering distribution costs. These efforts will lead to a decline in overall logistic cost and product price.

A much broader perspective in continuity planning is essential, as many threats to business survival lie outside the focal firm. Thus, resilience should be designed in supply chain development to mitigate vulnerability. Adoption of a mitigation strategy would enable a firm to manage operational risks effectively, sustain supply chain operation and recover from disruptions (Tang, 2006). These factors would enable supply chain operations to be more responsive to customer demand with less inventory and at lower cost (Faisal et al., 2006). Mitigation strategies should be incorporated into supply chain development.

### 2.2 Vulnerability mitigation strategy

Many firms lack awareness of the need to include analysis of supply chain vulnerability into their overall approach for maintaining business continuity. Drawing from the study by Oke and Gopalakrishnan (2008), mitigation strategies require specific approaches in handling low-likelihood high-impact risks based on analysis of supply chain vulnerability. Norrman and Lindroth (2004) suggest that mitigation strategies for daily operational accidents should be distinguished from those for uncertainties of a catastrophic nature based on probability and severity of the risk consequences. Juttner et al. (2003) define supply chain vulnerability as the propensity of risks to outweigh safety measures to the extent of causing supply chain disruptions. Each firm should plan an appropriate mitigation strategy by exploring the source of risks, analyzing the drivers

of supply chain vulnerability and measuring consequences. Hence, vulnerability mitigation strategy must be developed specifically to respond to dynamic changes in the environment.

Supply chains are vulnerable to risks arising from coordinating problems in supply and demand (Kleindorfer and Saad, 2005). Several studies have addressed the mitigation of risks in supply chains but have not separated mitigation strategies for different types of risk. Collaborative relationships have been the most sophisticated form of supply chain partnering (Harrington, 1998). Tyndall et al. (1998) suggest that supply chain partnerships move from general market transaction to cooperation, to coordination and finally to collaboration. Collaborative partnerships support visibility across the supply chain, development of supply chain flexibility, relationships between supply chain members and efficiency of inventory costs (Faisal et al., 2006). Muckstadt et al. (2003) acknowledge that collaborative relationship with other supply chain members ensures that the response alternatives to a disturbance are more effective.

From a strategy perspective, Gunasekaran et al. (2004) consider supply chain risk management as an expanding discipline that transforms the process of manufacturing and non-manufacturing operations to meet customer expectations. Formulating an effective and responsive operational strategy to a certain extent will be useful to mitigate supply chain vulnerability. Chopra and Sodhi (2004) propose that strategic adaptation to organization circumstances and a shared organization are two important foundations in strategy formulation. The essence of vulnerability mitigation strategy is to strike a balance between cost and effectiveness. In their approaches to mitigation strategy, researchers propose a number of substantial actions, such as information sharing (Lee and Wolfe, 2003; Tang, 2006), greater integration in supply chain activities (Kleindorfer and Saad, 2005; Faisal et al., 2006; Yang and Yang, 2009) and collaboration approaches with partners (Harland et al., 2003; Chopra and Sodhi, 2004).

Based on preliminary surveys and classifications found in literature, mitigation strategies should include supply chain visibility, supply chain flexibility, supplier development and inventory control. Harland et al. (2003) emphasize the importance of visibility, flexibility, supplier development and network mapping to create an efficient and resilience supply chain. Visibility, flexibility, supplier assessment and inventory control are essential in risk mitigation (Juttner et al., 2003; Chopra and Sodhi, 2004). Safety stocks require sufficient inventory control to generate stream material flows. These four types of mitigation strategies cover most of the important elements found in studies on reduction of supply chain vulnerabilities, as well as capture intensive coordination across organizations, which is a basic element in mitigation strategy.

Svensson (2004) indicates that an obscurity in the access to information beyond outbound suppliers and outbound customers, which causes a lack of transparency contributing to uncertainty. The uncertainty can increase costs due to overreactions throughout the supply chain (Childerhouse et al., 2003). Making an optimal decision is difficult because of the existence of nervousness. The nervousness could push unnecessary actions and redundancy efforts that make the

supply chain inefficient. Optimal decisions on the planning and implementation of supply chain strategy cannot be reached if the uncertainty is high (Juttner et al., 2003; Lee and Wolfe, 2003). Hence, achieving supply chain visibility should be considered first to increase supply chain effectiveness as part of mitigation efforts.

Securing flexibility in internal operation, suppliers and customers is useful to anticipate unpredictable factors arising from various internal and external sources in supply chain activities (Candace et al., 2011). Supply chain flexibility is widely seen as a strategic response to increasing uncertainty and competition (Merschmann and Thonemann, 2010). Supply chain flexibility significantly affects higher competitiveness and firm performance (Hatani et al., 2013). Flexibility in the design process and the design of the product provide protection against a changing market in terms of profit margin and production costs (Khan et al., 2008; Mohdzain et al., 2012). Supply chain flexibility provides an organization the ability to maintain an efficient operation and can be considered a strategic approach to achieve supply chain effectiveness.

The third approach to achieve supply chain effectiveness is to create collaborative relationships with suppliers. Supplier development programs can significantly help mitigate risk and increase efficiency. The challenge is to create conducive conditions to facilitate a collaborative working process. Greater willingness to work in partnership is required in the current business environment. Quick changes in the business environment have put manufacturing firms under pressure to improve quality, delivery and responsiveness while simultaneously reducing costs (Kannan and Tan, 2006). Outsourcing activities are considered by increasing the role of suppliers in the production process (Pralhalad and Hamel, 1990). Supplier development enables firms to better use their resources and increase the value added, and allows manufacturing firms to be more effective in responding changing needs. Hence, outsourcing allows firms to exploit the capabilities and use supplier technology to shorter product development and manufacturing cycle time in increasing supply chain efficiency.

The fourth approach to create an efficient supply chain is managing competitive and responsive inventory. Long-term and mutual goals with suppliers and customers in manufacturing are a critical factor for the successful implementation of effective production (Wu, 2003). To enhance long-term competitiveness, encouraging suppliers and customers to develop capabilities of efficient manufacturing and delivery practices is essential (Martha and Subbakrishna, 2002). Companies can minimize risks by working with a highly responsive supplier in inventory monitoring (Chopra and Sodhi, 2004). Inventory control is a key to inventory reduction, adapting to market variations more efficiently and enabling enterprises to respond to consumer demand more quickly while maintaining supply chain operation cost.

### 2.3 The role of risk management culture

Risk management aims to understand the effect of operational dynamics and complexities to provide a thorough understanding to supply chain members and analyze the effect

of risks on network structure (Hallikas *et al.*, 2004). The role of risk management is to guide appropriate strategic solutions in the disruption settlements to mitigate severe effects. Mitigation actions are required to curb vulnerability as a response to risk management analysis. Risk management culture is essential in enhancing the implementation of mitigation strategy and diffusion among business organizations. Highly reliable organizations are characterized by strong cultures and norms that reinforce their strategic objectives, which focus on policies and procedures in decisions to reduce internal and external risks (Grabowski and Roberts, 1997).

The need for formalized procedures for supply chain risk management within and between organizations emerges to cope with emerging issues that may affect supply chain continuity (Christopher and Peck, 2004). Pilbeam *et al.* (2012) find that shared value, scheme and culture within the supply network improves performance, control and viability. The lack of culture in risk management is an explanation for poor handling of supply chain disruption (Dowty and Wallace, 2009).

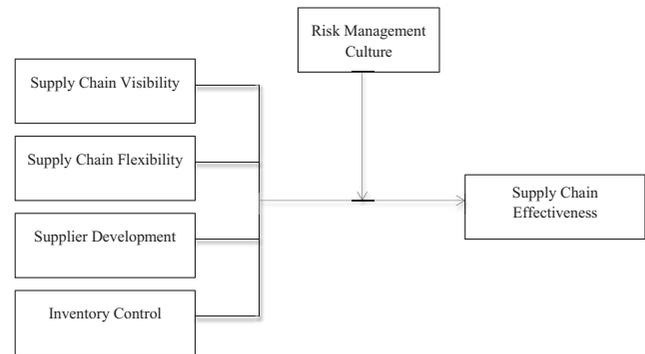
Risk management needs to be integrated into an organization's culture to provide legal path for risk management activities in an organization (Christopher and Peck, 2004). Organizations that proactively build risk management culture, defined herein as the ability to absorb and effectively respond to an exogenous shock into their organizations, are better able to react to and recover from supply chain disruptions (Argenti, 2002; Worthington *et al.*, 2009). Risk culture is defined as the consideration in risk management embedded formally within the decision-making processes at every level of the company operating within the culture of the organization (Christopher and Peck, 2004; Shah, 2009).

Risk management is essential to identify the potential sources of risks and vulnerability drivers in supply chain activities (Kersten *et al.*, 2006; Ozlen *et al.*, 2013). Risk taking processes must pass through institutional and planned rule structures to manage resources within the supply chain collectively justified through addressing the greater good (Juttner *et al.*, 2003). Organizational culture can be a powerful tool for managers to steer their organizations. Autry and Bobbitt (2008) mention that an important factor to counter vulnerability is creating and supporting an organizational culture that considers supply chain risks to maintain business continuity and operations. The development of a supply chain risk management culture is considered essential, as the influence of culture to operational, strategy and supply chain goals is significant (Williams *et al.*, 2009). Congruence between organizational culture and strategies is believed to enhance organizational performance (Alvesson, 2002).

### 3. Conceptual framework and hypotheses development

Based on our literature review, we propose that each type of mitigation strategy plays different roles in contributing to supply chain effectiveness. Figure 1 shows the proposed framework to identify the effects of vulnerability strategies on supply chain effectiveness. This study also examines the moderating effect of risk management culture on the

Figure 1 Proposed research framework



relationships between vulnerability strategies and supply chain effectiveness.

#### 3.1 Supply chain visibility and supply chain effectiveness

Supply chain visibility refers to the ability to access or share information, which is useful to supply chain operations and provides mutual benefits (Christopher and Lee, 2004). Supply chain visibility closes the gap between planning and implementation to improve cost and resilience. Supply chain visibility offers a complete view of the production process from outbound suppliers to the ultimate customers. Thus, supply chain visibility improves confidence and helps a firm maintain a lower level of inventory. An increase in visibility is positively correlated to reduced cost and increased business performance (Christopher and Lee, 2004).

Firms within a supply chain must always increase interactions with their partners to ensure visibility in improving efficiency and responsiveness to face a dynamic market (Kauffman *et al.*, 2012). Demand visibility reduces the need for redundancy and improves manufacturing effectiveness (Christopher and Peck, 2004; Caridi *et al.*, 2010). Greater visibility of key information from suppliers is key to improving under-performing supply bases and reducing the cost of internal inefficiencies. Supply chain visibility is needed in managing the upstream and downstream relationships to enhance product value in the market at less cost as a whole. As such, the following hypothesis is developed:

H1. Supply chain visibility positively affects supply chain effectiveness.

#### 3.2 Supply chain flexibility and supply chain effectiveness

Supply chain flexibility is the ability to adapt to changes in the global competitive environment in a fast and cost-effective manner. Supply chain flexibility is a strategic initiative that enables the firm to respond rapidly to changes in the market, including unanticipated actual disruptions in the supply chain (Swofford *et al.*, 2006). Supply chain flexibility is the source to maintain sustainable performance in anticipating the changes in customer needs (Lee and Wolfe, 2003; Berle *et al.*, 2013). Fawcett *et al.* (2000) conclude that flexibility is a required capability that helps firms enhance its performance, sustain resources and manage markets.

Volume flexibility is significantly related to operational cost reduction and positively responds to market volatility (Swafford *et al.*, 2006). Flexible supply chain allows the firm to adapt quick change in the environment and manage demand volatility. Manufacturing flexibility provides the organization the capability to produce various products, which in turn improves capacity utilization to improve production efficiency. This operational flexibility allows the company to manufacture products in small batch sizes to overcome the effect of demand fluctuation (Satyajit, 2013). Therefore, the following hypothesis is developed:

H2. Supply chain flexibility positively affects supply chain effectiveness.

### 3.3 Supplier development and supply chain effectiveness

Many firms and organizations externalize a wide range of functions that are previously produced internally (Harland *et al.*, 2003; Whitman *et al.*, 2010). Outsourcing activities are strategic responses to conditions of uncertainty and dependence from the scarcity of resources within the organization (Hätönen and Eriksson, 2009). The portion of outsourcing activities has increased substantially ranging from servicing to production of major components. Malhotra (2014) emphasized that outsourcing activities enable the organization to manage labor and manufacturing more effectively to reduce overall production cost.

Supplier development is any effort to improve the supplier's performance and capabilities to meet the organization's current and future needs (Prahinski and Benton, 2004). The supply chain literature emphasized the importance of supplier development to support a firm's operations strategy to ensure that suppliers' performance and capabilities meet the needs of the buying firm (Monczka *et al.*, 1993). Supplier development plays a critical role to promote performance improvement and contribute strategically to the overall organizational effectiveness. Goal congruence in the form of supplier development is the most substantial element in the network relationships to mitigate vulnerability. Supplier development is a guarantee for sustainable production, increasing the efficiency of supply chain in terms of cost and quality to manage environment uncertainty. Therefore, the following hypothesis is developed:

H3. Supplier development positively affects supply chain effectiveness.

### 3.4 Inventory control and supply chain effectiveness

In supply chain management, the control of material flow from suppliers of raw material to final customer is crucial to maintain efficiency and sustainability. Inventory management is the function that pertains to the decisions about stocks in an organization, and this function is known as inventory control (Waters, 2003). Inventory control is part of the mitigation strategies to ensure that the right amount of inventory is maintained to retain the service level to customers. The adoption of efficient inventory control allows an organization to reduce inventories without increasing other costs by balancing the goals among purchasing, production and marketing (Axsater, 2006). Bragg (2011) defined inventory

control as a set of policies and operating procedures that are designed to maximize a company's use of inventory from minimum inventory investment to generate maximum profits.

Inventory control refers to the capability of the firm to design and administer logistics system to manage movement and positions of raw materials, as well as stage of process and inventories at the optimum level (Wincel, 2004). An efficient inventory management practice has a positive effect on the suppliers' ability, leading to improved performance. Reliable suppliers that support optimum inventory level can have a profound effect on the overall supply chain to increase competitiveness. By contrast, the flows of materials are monitored to guarantee supply reliability (Germain *et al.*, 2008). Inventory control manages material flows in an effective method through balancing between cost and effectiveness. To determine the appropriate inventory levels based on the critical level of supply to avoid production disruptions is crucial (Elkins *et al.*, 2005). Inventory control is a tool in trade-offs analysis to judge the balancing of the inventory cost. Strategic decisions to provide inventory at potential critical points can be extremely beneficial in the creation of effective supply chain. Therefore, the following hypothesis is developed:

H4. Inventory control positively affects supply chain effectiveness.

### 3.5 Moderating effect of risk management culture

The requirement for the adoption of supply chain risk management is increasing, as the competition between networks has become prominent in current dynamic environment (Kersten *et al.*, 2006). Many firms need to collaborate closely with their suppliers and customers to deliver sustainable competitive advantage. As these relationships create dependence, all members of the supply chain should agree on a common risk culture within the network. Van Vuuren (2000) stated that the success of a strategy is related to the congruency between companies' strategies and culture. Studies have increasingly found risk management culture as the guide for risk mitigating strategies (Clarke and Varma, 1999; McShane *et al.*, 2011). Risk management culture is embedding formally risk management within the decision-making processes at every level of the company operating within the culture of the organization (Christopher and Peck, 2004; Braunscheidel and Suresh, 2009). It is suggested that risk management culture can impact on managers' ability to process risk and disruption information, rationalize and exercise discretion in their vulnerability mitigation decision-making processes. The risk management culture within an organization is important to transform vulnerability awareness into mitigation actions. The risk management culture coupled with strategic mitigation measures tends to reduce vulnerability and thus contributes to a resilient supply chain (Christopher, 2003).

When risks and uncertainties could bring severe or even catastrophic disruption to the supply chain, these vulnerabilities must be addressed at a strategic level to create a reliable integrated structure (Lee, 2002). In supply chain risk management, cultural factors clearly influence mitigation strategy and responses to settle disruptions (Braunscheidel

and Suresh, 2009). The risk management culture within the organization should be supportive of mitigation strategies. The increasing risk exposure within the business environment creates the requirement to engender a culture of concern for risk management in everyone. Haque and Islam (2013) emphasized the importance of employee's participation to support strategic implementation as part of the organization culture. Cultural variable is the prerequisite of a successful strategic implementation. Autry and Bobbitt (2008) found that the orientation of employees toward supply chain risks issues in decision-making may improve organizational performance. Risk management must be embedded into organizational cultures to ensure resiliency in the settlement of any supply chain disruption (Sheffi and Rice, 2005).

Risk management controls operations to reduce vulnerability, while a mitigation strategy defines how the supply chain should operate to mitigate vulnerability. A mitigation strategy is an iterative process that evaluates the cost-benefit trade-off analysis of a supply chain operation (Happek, 2005). The essence of risk management in a supply chain is to make decisions that optimally align mitigation strategy processes and trade-off analysis in minimizing risks (Cucchiella and Gastaldi, 2006). Risk consideration in supply chain activities, the involvement board of directors in risky decisions and a shift from adversarial relationships to collaboration and partnership among supply chain members in risk management should strengthen the implementation of the mitigation strategy (Christopher, 2003). Risk management culture contributes to resilience by endowing employees with a set of principles regarding the proper response when the unexpected disruption does occur (Bredell and Walters, 2007). It suggests that risk management culture will help firms to implement mitigation strategies more effectively; thus, it is expected that the existence of a higher risk management culture will enhance the positive effect of mitigation strategies on supply chain effectiveness. In addition, according to Asbjørnslett (2009), to ensure the complete implementation of vulnerability strategies, firms must use both internal and external strategies. Therefore, a risk management culture is essential for the implementation of vulnerability mitigation strategies and for better supply chain performance. Therefore, the following hypotheses have been developed:

- H5. Risk management culture moderates positively the effects of (a) supply chain visibility, (b) supply chain flexibility, (c) supplier development and (d) inventory control on supply chain effectiveness.

## 4. Research methodology

### 4.1 Measure of constructs

This study used a survey instrument consisting of four sections, namely, firms' basic information, risk mitigation strategies (supply chain visibility, supply chain flexibility, supplier development and inventory control), supply chain effectiveness and risk management culture. To ensure content validity, the survey items were derived from previous studies. The supply chain visibility items were adapted from Chen et al. (2010) and Redondo and Fierro (2008). The scales for supply chain flexibility were adapted from Pujawan (2004) and Braunscheidel and Suresh (2009). The items for supplier

development were adapted from Modi and Mabert (2007) and Paulraj et al. (2006). The items for inventory control were adapted from Wincel (2004) and Li et al. (2006). Managers have to indicate the level of adoption of each dimension for the implementation of a mitigation strategy in their firms. The items for risk management culture were adapted from Williams et al. (2009). A five-point Likert scale ranging from "Very Low Extent" (1) to "Very High Extent" (5) was used to measure each item of these variables. The scales for supply chain effectiveness were adapted from Fugate et al. (2009), Craighead et al. (2009) and Lorentz et al. (2010). The respondents were asked to rate their unit's actual performance compared to budgeted and planned performance, based on the previous fiscal year's results. The items of supply chain effectiveness were measured using a five-point Likert scale ranging from "Much Worse" (1) to "Much Better" (5) to rate the performance improvement.

### 4.2 Sample and data collection

The sampling frame of this study consists of all medium to large manufacturing firms in Indonesia. Indonesia is selected because of its unique geographical conditions. Specific impediments to supply chain activities in Indonesia include the vast expanse of territory covering thousands of islands, unpredictable weather patterns causing floods and disrupting maritime transport, as well as Indonesia's seismically active location at the juncture of two tectonic plates. History demonstrated that Indonesia is a country prone to environmental disasters, such as earthquake, volcanic eruptions and tsunami (Vanany et al., 2007), and without preparation, environment vulnerability could have a serious effect. Compounding these challenges are economic issues, such as high inflation, exchange rate volatility and infrastructure deficits, eroding competitiveness. Hence, to analyze the perspective of manufacturing managers in Indonesia related to vulnerability mitigation strategy is relevant.

The sampling list was obtained from the Badan Pusat Statistik database. Indonesia has 26,082 registered medium to large manufacturing firms. The survey was conducted using a structured mail questionnaire sent to the corresponding respondents in each firm. Data were collected in time range from February 10 and April 10, 2015. Among 700 questionnaires sent to the firms, 218 were collected. A return rate of 31.1 per cent was obtained. Nine incomplete questionnaires were invalid. The percentage of usable response was approximately 29.9 per cent.

The power of 209 samples was measured using G\*Power version 3.1.9.2 (Faul et al., 2009). A power of 0.999 was obtained using this software with an effect strength value of 0.15 and a statistical significance level ( $\alpha$  level) of 0.05. This yield exceeded 0.80 and indicated that the power of the current sample was satisfactory (Chin, 2001). These results indicated that the proposed sample size has the requisite power to reject the null hypotheses (Faul et al., 2009).

### 4.3 Analysis

To test the research model, the current study used the partial least squares (PLS) technique of structural equation modeling using SmartPLS Version 3.0. This technique was selected

because of the exploratory nature of the study (Hair *et al.*, 2011). Based on the recommendation of Hair *et al.* (2013), the current study applied a two-step approach for data analysis (Nikbin *et al.*, 2015; Zailani *et al.*, 2015). The first step analyzed the model for measurement, and the second evaluated the relationships among the structures of the underlying constructs.

## 5. Results

### 5.1 The sample

The final sample consisted of 63 (30.1 per cent) food, beverage and tobacco firms; 57 (27.3 per cent) textile and apparel firms; 33 (15.8 per cent) chemical firms; 32 (15.3 per cent) metal, equipment and machinery firms; and the remaining 24 (11.5 per cent) firms were from other miscellaneous industries. The majority of the firms (85.2 per cent) were highly dependent on domestic input, and only 31 firms (14.8 per cent) heavily relied on imported components and materials. Most of the products (77.0 per cent) were for the domestic market because Indonesia has a very huge potential market. In terms of the number of employees in the firm, the data indicated that 80.9 per cent of the firms have more than 100 employees.

### 5.2 Measurement model results

The reflective constructs were examined in terms of reliability and validity. The composite reliability (CR) was equivalent to the Cronbach's alpha and was measured in relation to internal reliability. Table I shows that the CR of all the constructs was above 0.7, which satisfied the rule in Hair *et al.*'s (2013) study. Hair *et al.* (2010) recommended the acceptance of items with a minimum loading of 0.7. The reliability of individual items was reasonably judged, given that all the scales reported loadings that exceeded 0.7. The average variance extracted (AVE) was used to evaluate the convergent validity; this value exceeded 0.5 in all the constructs. This finding indicated the satisfactory convergent validity of these constructs (Fornell and Larcker, 1981).

Two techniques were used to evaluate the discriminant validity in the constructs (Zailani *et al.*, 2016; Yusof *et al.*, 2016). First, indicator cross-loadings were investigated. Each opposing construct did not exceed any indicator load (Hair *et al.*, 2012). Second, the value of the intercorrelations between the construct and the other model constructs should be surpassed by the square root of the AVE of a single construct (Table II). Both analyses confirmed the discriminant validity of all the constructs. Table II shows that among vulnerability mitigation strategies, supplier development is highly adopted by Indonesian firms (mean = 3.710). The supply chain effectiveness was satisfactory (mean = 3.561).

### 5.3 Assessment of the structural model

The measurement model generated satisfactory results. Thereafter, the structural model was assessed. The accuracy of the predictions from using this model was determined through the explained variance portion. The model can consider 48.4 per cent of supply chain effectiveness variances. In addition to estimating the  $R^2$  magnitude, the predictive relevance evaluation measure developed by Stone (1974) and

Geisser (1975) was incorporated as another tool to determine the model fit. Thus, the ability of the model to estimate clear indicators of underlying constructs can be assessed. The Stone–Geisser  $Q^2$  (cross-validated redundancy) value was calculated to measure the predictive relevance according to a blindfolding process performed in PLS. Chin (2010) indicated that the model displays a predictive relevance if the value of  $Q^2$  is greater than zero. The current research obtained a cross-validated redundancy of 0.361, which was considerably higher than zero. Thus, the model exhibited an acceptable fit and high predictive relevance.

Non-parametric bootstrapping was applied to test the structural model (Wetzels *et al.*, 2009) with 2,000 replications. Table III presents the structural model that results from the PLS analysis. All the vulnerability mitigation strategies except inventory control have positive significant effect on supply chain effectiveness. Therefore,  $H1$ ,  $H2$  and  $H3$  were supported, whereas  $H4$  was not supported.

The product indicator approach (mean-centered) was used to create an interaction construct (Hair *et al.*, 2013). The CR and AVE of the interaction constructs met the criteria for reliability and convergent validity. The results indicated that the interaction of risk management culture and supply chain visibility ( $\beta = 0.227$ ,  $p < 0.01$ ) and risk management culture and supplier development ( $\beta = 0.247$ ,  $p < 0.01$ ), positively affected the supply chain effectiveness significantly. Hence,  $H5a$  and  $H5c$  were supported, whereas  $H5b$  and  $H5d$  were unsupported.

Figures 2(a) and 2(b) illustrate that supply chain visibility and supplier development strategies have no effect on supply chain effectiveness of firms with low risk management culture, but have positive effects among firms with high risk management culture.

## 6. Discussion

The present study identifies the relationship between vulnerability mitigation strategies and the supply chain effectiveness of manufacturing firms in Indonesia and the effect of risk management culture on the relationships between vulnerability mitigation strategies and the supply chain effectiveness. Our findings suggested that supply chain visibility, supply chain effectiveness and supplier development had a positive and significant effect on supply chain effectiveness. Moreover, risk management culture positively moderated the effects of supply chain visibility and supplier development on supply chain effectiveness. In addition, the descriptive results indicated that supplier development was the most common strategy. Manufacturing firms in Indonesia adopted this strategy to mitigate the negative effect of vulnerability.

The significant relationship between supply chain visibility and supply chain effectiveness is parallel to the studies conducted by Christopher and Lee (2004) and Kauffman *et al.* (2012). These researchers claimed that supply chain visibility increased confidence to support an efficient operation. Information sharing to increase visibility improved supply chain responsiveness to anticipate supply and demand fluctuations. Supply chain visibility enables a firm to shorten its delivery process and improve product availability, increasing the supply chain effectiveness. Furthermore,

Table I Measurement model evaluation

Constructs	Items	Factor loadings	CR	AVE
Supply chain visibility (SCV)	We and our partners inform in advance of changing needs	0.812	0.925	0.637
	<i>We and our partners share knowledge of core business process</i>	0.760		
	<i>We and our partners keep each other informed about customer's future needs</i>	0.857		
	<i>We and our partners communicate future strategic needs</i>	0.805		
	<i>We continue to improve integration of activities across supply chain</i>	0.781		
	We and our partners share problems, market and inventory information	0.755		
	We and our partners collaborate to monitor product movement	0.811		
Supply chain flexibility (SCF)	It is possible to switch the purchase of items from one supplier to another	0.866	0.928	0.681
	<i>It is possible to change the quantity of supplier's order</i>	0.818		
	<i>Different modes of transportation are available in delivering products to the customers</i>	0.879		
	<i>Production capacity is sufficient to accommodate an increase in demand</i>	0.807		
	Overtime or temporary worker is possible to cope with short term demand fluctuation	0.756		
	Most suppliers are capable of producing a small quantity due to relatively low setup costs	0.821		
	We and our partners share problems, market and inventory information	0.755		
Supplier development (SD)	Used multiple suppliers for the purchased item to create competitive pressure	0.823	0.917	0.614
	<i>Site visits to the supplier to help them improve performance</i>	0.858		
	<i>Conducted training and education programs supplier personnel</i>	0.815		
	Consideration to enhance business relationships in the future	0.708		
	Assessed the supplier's performance through a formal supplier evaluation system	0.732		
	Development of targeted quality and other improvement benchmarks within the suppliers	0.802		
	We involve key suppliers in the product design and development stage	0.733		
Inventory control (IC)	Our firm provides permanent and visible storage for material supply	0.761	0.907	0.710
	<i>Our firm sets up threshold for each type of materials referring to production fluctuation</i>	0.751		
	<i>Our firm maps material flows from the suppliers up to the customers</i>	0.750		
	<i>The position of inventory is always being monitored</i>	0.788		
Supply chain effectiveness (SCE)	Transportation cost	0.756	0.887	0.568
	Warehousing cost	0.793		
	Inventory cost	0.646		
	Logistic administration cost	0.709		
	Product cost	0.801		
	<i>Order delivered in the right quantity, specification and without damage</i>	0.809		
	Top management involvement in risk decisions	0.764		
Risk management culture (RC)	<i>Our firm creates a supply chain risk focus among all employees</i>	0.859	0.906	0.616
	<i>Our firm makes sure that supply chain risk the first thing on the mind of all employees</i>	0.827		
	<i>Our firm makes supply chain risk the norm for all employees</i>	0.749		
	<i>Our firm dedicates efforts to create a supply chain risk-focused workforce</i>	0.763		
	<i>Our firm makes sure that all employees are vigilant toward supply chain risk</i>	0.741		

Notes: CR = Composite Reliability; AVE = Average Variance Extracted

information exchange activities have positive effects to reduce the time to respond to request, increase the frequency of on time delivery and responsiveness to change in demand. Hence, the supply chain visibility as a part of mitigation efforts

can increase supply chain effectiveness by decreasing uncertainly on demand and supply. Childerhouse *et al.* (2003) stated that uncertainty can increase costs because of overreactions throughout the supply chain. As such,

Table II Discriminant validity coefficients

Constructs	Mean	SD	SCV	SCF	SD	IC	SCE	RC
SCV	3.528	0.552	<i>0.798</i>					
SCF	3.542	0.638	0.680	<i>0.825</i>				
SD	3.710	0.651	0.336	0.346	<i>0.784</i>			
IC	3.063	0.611	0.582	0.626	0.355	<i>0.841</i>		
SCE	3.561	0.677	0.381	0.457	0.395	0.372	<i>0.754</i>	
RC	3.413	0.613	0.014	0.013	-0.042	0.031	0.099	<i>0.785</i>

Note: Diagonals (in italics) represent square root of the AVE

Table III Path coefficients and hypothesis testing

Hypothesis	Relationship	Path coefficient	Decision
<b>Main model</b>			
H1	SCV → SCE	0.209*	Supported
H2	SCF → SCE	0.304***	Supported
H3	SD → SCE	0.258**	Supported
H4	IC → SCE	0.081	Not supported
<b>Moderating effect of risk management culture</b>			
–	RC → SCE	0.151	–
H5a	RC × SCV → SCE	0.227**	Supported
H5b	RC × SCF → SCE	0.093	Not supported
H5c	RC × SD → SCE	0.247**	Supported
H5d	RC × IC → SCE	-0.062	Not supported

Notes: t values are computed through bootstrapping procedure with 209 cases and 2,000 samples; \*  $p < 0.05$ ; \*\*  $p < 0.01$ ; \*\*\*  $p < 0.001$  (one tail)

manufacturing firms aspiring to improve their supply chain effectiveness by mitigating the effect of vulnerability should practice supply chain visibility strategy.

The results indicated the significant effect of supply chain flexibility on supply chain effectiveness. These findings confirmed the results of previous studies that suggested the importance of supply chain flexibility on the supply chain effectiveness (Lee and Wolfe, 2003; Berle et al., 2013; Fawcett et al., 2000; Hatani et al., 2013). Supply chain flexibility enables firms to respond rapidly to changes in the market. Flexible supply chain enabled the manufacturing firm to respond rapidly to quick change in the environment and manage demand volatility. Hatani et al. (2013) acknowledged the importance of flexibility in meeting customer demands and improving responsiveness. Merschmann and Thonemann (2010) suggested supply chain flexibility as a strategic response to increasing uncertainty and competition. Overall, the current study determined that the influences of supply chain effectiveness, more than other vulnerability mitigation strategies, suggested the importance of flexibility to mitigate the influence of vulnerability.

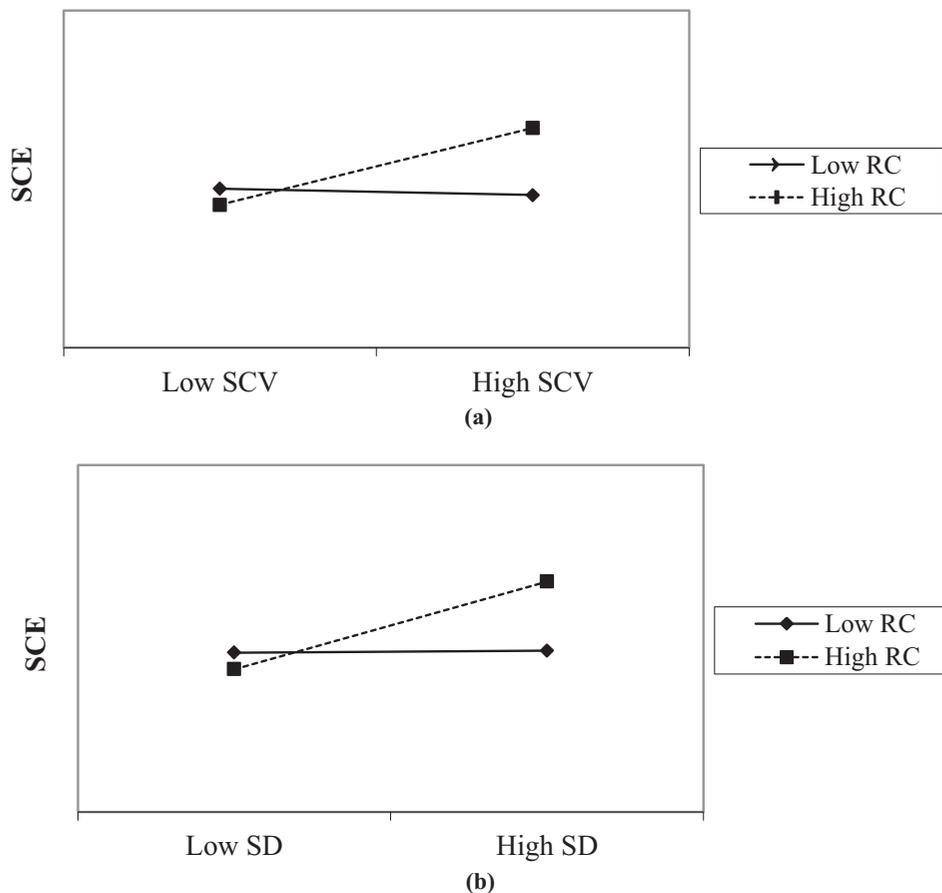
The significant relationship between supplier development and supply chain effectiveness was consistent with the studies conducted by Monczka et al. (1993), who found the importance of supplier development to support a firm's operations strategy to ensure that suppliers' performance and capabilities meet the needs of the buying firm. The improvement of supplier performances through supplier development program can secure high-quality and on-time supply delivery and thus reduce the possibilities of disruption. The active engagement of the supplier, as well as supplier

selection as part of supplier development program, can facilitate a conducive relationship between buyer and supplier, improving firm performance. Supplier development increases the buyer firm's capability to secure competitive position and maintains the service level to the customers in response to rapid increases in market share. As such, a closer relationship between supplier and buyer is required.

The results indicated that inventory control has no significant effect on supply chain effectiveness, which was inconsistent with the findings of previous studies, such as Martha and Subbarkrishna (2002) and Chopra and Sodhi (2004). Inventory control might help reduce the risk of an inventory shortage, but it leads to increased costs in the form of an increased inventory level and monetary requirements. Therefore, the results show an insignificant effect of this strategy on supply chain effectiveness. As such, the proactive collaborations with the suppliers and customers are required in mitigation strategy, rather than reactive effort that focuses on inventories. The effect of preventive strategies can mitigate the effect of sources of vulnerability before a disruption occurred in relation to the improvement of supply chain performance. Supply chain visibility, supply chain effectiveness and supplier development as preventive strategies reduce the probability of risk occurrence. Preventive strategies intended to decrease the level of risks.

The results showed that risk management culture moderated the effects of supply chain visibility and supplier development on supply chain effectiveness. The effects of supply chain visibility and inventory control on supply chain effectiveness were not moderated by risk management culture. These results implied that with a strong risk management

Figure 2 Interaction effect of risk management culture



Notes: (a) Supply chain visibility; (b) supplier development

culture among the employees, the effects of supply chain visibility and supplier development strategies on supply chain effectiveness will be greater. Hence, managers of manufacturing firms should work to enhance employee vigilance toward supply chain risk to create a supply chain risk-focused workplace and establish supply chain risk as a norm for all employees. All employees in the supply chain should agree on a common risk management culture within the network.

The moderating effect of risk management culture on the effects of supply chain visibility and supplier development strategies on supply chain effectiveness was significant because the implementation of these strategies needs greater involvement of top management in risk decision and participation of employees. On the other hand, the insignificant effect of risk management culture on the effects of supply chain flexibility and inventory control was attributed to the lower participation of the employees in this strategy than the others. It means sharing knowledge of core business processes with partners, communicating future strategy needs with partners and improving the integration of activities across the supply chain as supply chain visibility practices and conducting training programs for supplier personnel and assessing the supplier's performance as supplier development needs higher involvement of top management and

participation of employees compared to sourcing strategies to allow for the switching of suppliers (supply chain flexibility) and to control the material flow from the suppliers of raw materials to the final customer (inventory control). Therefore, a risk-focused workforce is needed to implement supply chain visibility and supplier development strategies in a more effective way.

## 7. Implications of the study

From an academic perspective, our research developed the concept of supply chain effectiveness by recognizing the role of vulnerability mitigation strategies in supply chain effectiveness. This study extended previous research conducted in developed countries and provided great potential by advancing the understanding between the vulnerability mitigation strategies and supply chain effectiveness among Indonesia's manufacturing firms. This research also contributed to the literature by examining the moderating effects of the risk management culture on the relationship between vulnerability mitigation strategies and supply chain effectiveness. To the best of our knowledge, our research is the first to present such theoretical and empirical examinations.

This study illustrated many implications for the managers of manufacturing firms. The firms must adopt strategies to improve their ability to respond rapidly and cost effectively to unpredictable disruptions, including natural disasters (i.e. sea level rise and earthquakes), man-made disasters (i.e. terrorist actions and civil unrest) and financial disasters (i.e. rising fuel and raw material prices). It is very important for the managers to know and understand the risks involved in supply chains. The interdependence of the risk may result in a chain of risk and increase the costs of mitigations. One risk may lead to various other disruptions and cause a negative effect on supply chain effectiveness. It is, therefore, essential to adopt vulnerability mitigation strategies as preventive actions. If the findings of this study were adopted, then the manufacturing firms can mitigate the sources of vulnerability and manage their supply chains in an effective way. The findings from this study offered managers an audit tool to determine which mitigation strategies should be deployed to support the supply chain mitigation efforts. The significant effect of supply chain visibility, supply chain effectiveness and supplier development on supply chain effectiveness suggest these three strategies to the managers of manufacturing firms as three effective vulnerability mitigation strategies which can improve supply chain management to achieve an overall higher value. Specifically, firms can compare their current strategies with the effective mitigation strategies. Strategic benchmarking entails the selection of the right variables, monitors performance on those variables and then identifies gaps through gap analyses. Gap analyses then lead to specific continuous improvement projects. In the context of this study, such an endeavor can be conducted with respect to mitigation strategies. In the Indonesian context, investment in supply chain visibility, supply chain flexibility and supplier development makes sense. One particular pragmatic tool is to test the viability of the different mitigation strategies by focusing on process improvement projects that aim to enhance supply chain effectiveness. Thus, managers of manufacturing firms should focus their attention to the management of daily supply chain activities in which they have to be effective when they deal with a turbulent environment.

The moderating impacts of risk management culture on the effects of supply chain visibility and supplier development on supply chain effectiveness suggest that high risk management culture allows companies to deliver superior performance while implementing supply chain visibility and supplier development strategies. From this perspective, we view that the proper alignment between supply chain strategies' visibility and supplier development strategies and risk management culture can offer benefits to companies aiming to achieve an effective supply chain goal. Therefore, managers should give importance to risk management culture. Risk management culture can become a tool to provide the legal path for risk decisions in a supply chain operation.

## 8. Limitations and future studies

Although the objective of the study was successfully accomplished, its limitations should be considered before presenting a generalization of the results. First, this study was based on multiple manufacturing sectors in Indonesia. The population of Indonesia manufacturing firms that are

considered exemplars in mitigating risks was small, preventing in-depth investigation into any one single industry. The results of this study should be drawn cautiously when referring to non-manufacturing firms and firms outside Indonesia. In addition, future research should focus on a certain industry as the effect of vulnerability strategies on supply chain effectiveness may differ among different industries. The research could also compare the adoption of mitigation strategies between two industries with a larger sample. Second, the survey in this study targeted the medium to large establishments; hence, small establishments may not be well-represented in this study. Small firms usually lack of information, resources and capital to deal with environment uncertainties. Lack of knowledge and lower level of implementation in risk management to respond to the change in the environment are typical for small firms. Small firms have limited capabilities; hence, they may view supply chain vulnerabilities differently. Thus, mitigation strategies adopted by small firms should be differentiated from mitigation strategies adopted by medium to large firms. Future studies could apply the research model to small firms. Furthermore, similar research could be implemented in other Asian countries with high occurrence of natural and man-made disasters. Third, the data were collected from a single informant from each firm. Most firms, especially medium ones, involve groups of executives who make decisions on vulnerability mitigation strategies. Therefore, we suggest that future research should collect data from multiple informants in each firm. Furthermore, future research may consider the use of other moderator variables to test the relationships between vulnerability mitigation strategies and supply chain effectiveness. Finally, in this study, effectiveness was measured through self-reported items. Future studies can measure supply chain effectiveness using the real data of the manufacturing firms.

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