Supply chain risk management: manufacturing- and service-oriented firms

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Abstract

Purpose – A risk, when it occurs, causes negative effects on outputs. Typically, risks are not independent as multiple risks occur simultaneously. The purpose of this paper is to compare the impact various risks have on the performance of manufacturing-oriented and service-oriented firms from a supply chain (SC) perspective.
Design/methodology/approach – First, SC risks were identified and classified into two criteria: context and probability. Then, the different characteristics between manufacturing- and service-oriented firms were distinguished by the theory of goods-dominant logic (GDL) and service-dominant logic (SDL). Structural equations modeling and multiple-group analysis were then used to validate research hypotheses and compare the two groups.
Findings – The empirical evidence, gathered from the Vietnamese construction sector, indicated that in a serious situation all of the five risks proposed occur at the same time, thus the remarkable 87.1% variance in SC performance was explained. Furthermore, this rate is significant when the two groups are compared: manufacturing-oriented firms (88.3 percent) and service-oriented firms (85.6 percent), implying that risks in the manufacturing-oriented group have a greater effect on SC performance. While manufacturing-oriented companies should pay close attention to the operational and demand risks that adversely affect SC performance, they should treat information risk as an opportunity to improve. Service-oriented companies, however, need to manage supply risk which, in their case, can be attributed to a 51.2 percent variance in SC performance. Moreover, service quality can also be improved remarkably if information risk is well managed.
Research limitations/implications – This study provides a detailed picture of the relationship between risks and performance in the SC. Risks are illustrated as affecting the SC performance simultaneously, (not separately) and so the approach outlined here will give firms a comprehensive view of their SCs and provide guidelines for predicting the impact risks will have on the SC performance. Moreover, by comparing manufacturing- and service-oriented firms, a thorough overview of risk behaviors is provided and appropriate solutions for each type of company can be determined.
Originality/value – The "novelty of approach" of this study is in applying GDL and SDL theory to classify the manufacturing-oriented and service-oriented firms. The different characteristics between the two groups are identified and explained in terms of resources, value, network, effectiveness vs efficiency and communication, thus providing an insight into risk management activities in the SC network.

Keywords Risk management, Supply chain management, Risk
Paper type Research paper

1. Introduction

Risks can exist in virtually all firms and although the firms in question may be doing everything very well, risks are still evident (Ho *et al.*, 2015). While risks, when they occur, can cause serious problems for firms/their supply chain (SC) (Ellis *et al.*, 2010), sometimes they can actually create opportunities for companies (Jüttner, 2005). Determining the degree of impact risks will have, is something any firm would like to know.

Numerous studies have been carried out to quantify the potential degree of risks. Some researchers have examined the effect each risk has on different outputs (Zsidisin and Ellram, 2003; Kim and Chavas, 2003; Xu *et al.*, 2010; Mitra *et al.*, 2013; Huong Tran *et al.*, 2016), meanwhile others aimed at a wider picture by covering various risks in the SC network (Ho *et al.*, 2015; Wagner and Bode, 2008).

Ho *et al.* (2015) argued that, as multiple risks occur concurrently, they are not independent of each other. In a grave situation, numerous risks occur simultaneously and if

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there are no appropriate contingency plans, they will engender devastating consequences for firms/their SC. For instance, on March 11, 2011, the Tōhoku earthquake in Miyako (Iwate Prefecture, Japan), which lasted approximately six minutes, and the powerful tsunami waves that followed caused a massive loss of lives and wealth. The economic cost has been estimated at US$235 billion, making it the costliest natural disaster in history. Thus, when considering the relationship between risks and outputs, it is imperative to investigate the impact different risks will have on various dimensions of output (Wagner and Bode, 2008). This, on the one hand, determines the "real" effect risks will have on outputs, while, on the other hand, and more importantly, this approach provides an extensive picture of the relationship between these two concepts.

Naldi *et al.* (2007) stated that risk behaviors depend on the organizational context. Firms have different characteristics, for example manufacturers and service providers (Sengupta *et al.*, 2006), and so the impact risks will have will also vary (Subramaniam *et al.*, 2009; Moses and Savage, 1994). Lovelock and Gummesson (2004) identified the following four commonly-used ubiquitous differences between manufacturers and service providers. These are known as IHIP:

(1) inseparability of production and consumption;

(2) heterogeneity;

(3) inventoriability; and

(4) perishability.

Modern-day industry has evolved from the time when its relentless focus was on a manufacturing process independent of associated service(s), to one that now offers manufacturing and associated service(s) of the highest degree bundled together (Sengupta *et al.*, 2006). Nowadays, an organization owns the manufacturing division that produces its finished products and its service departments supply the required resources for sales and after-sales services. Consequently, it is a challenging task to distinguish a manufacturer or a service provider (Cudney and Elrod, 2011).

In this paper, the theory of goods-dominant logic (GDL) and service-dominant logic (SDL) developed by Vargo and Lusch (2004) is applied to identify two types of businesses: manufacturing-oriented firms and service-oriented firms. To provide an insight into the risk management activities of the two groups, we compared them in terms of resources, value, network, effectiveness vs efficiency and communication.

Additionally, since competition moves from firms toward SCs, the scope of risks has now been extended to the whole SC network (Kumar *et al.*, 2014). In the meantime, current knowledge is still quite limited as most articles on SC risks are either simulation or case study-based. Results from large-scale empirical studies are scarce and mostly descriptive (Wagner and Bode, 2008). We expect that, through a large-scale survey of the Vietnamese construction sector, this study will be able to provide a clear and thorough view of SC risks in manufacturing- and service-oriented firms, thereby proposing appropriate solutions for each type of company.

The rest of the paper is organized as follows. A review of the literature is undertaken to identify the critical SC risks in Section 2, before a theoretical framework is proposed. In the Section 3, firms are classified into two groups – manufacturing-oriented and service-oriented – using the theory of G-D and S-D logic. The research methodology and results are then presented before the discussion section that considers the results of this study which, in turn, helps to identify the topics for future research, and draws conclusions in Section 7.

2. SC risks and research hypotheses

Recently, several publications have debated the conceptual clarity of "risk" used in the SC management; however, there is still no common agreement as to how to define this concept.

Risk is an elusive construct that has a variety of meanings, classifications and interpretations depending upon the field of research (Wagner and Bode, 2008). In the general discussion of risk, there is a persistent tension between two different points of view regarding its definition:

(1) Risk as purely danger:

- Researchers sharing this view agree that risk has primarily negative consequences, thus corresponding to the typical human perception. Particularly, Ellis *et al.* (2010) outlined SC risk as "an individual's perception of the total potential loss associated with the disruption of supply of a particular purchased item from a particular supplier." March and Shapira (1987) empirically analyzed the way that managers perceive and react to risk, concluding that the majority tend to magnify its "downstream" consequences. According to an annual survey from the Business Continuity Institute in 2015, organizations today face more than 24 sources of risks; all with differing levels of impacts and consequences. The most common consequences of these risks are the loss of productivity (58 percent), customer complaints (40 percent) and increased working costs (39 percent), with annual cumulative losses of at least €1 million a year due to SC disruptions.

(2) Risk as both danger and opportunity:

- In classical decision theory or common practices in business fields of research (e.g. finance), risk can be examined as "the fluctuations around the expected value of a performance measure." Scholars supporting this viewpoint argue that risk is equated with variance and, consequently, has both a potential "upside" and "downside." For instance, March and Shapira (1987, p. 1404) defined risk as "variation in the distribution of possible outcomes, their likelihoods, and their subjective values." Extending the scope of risk, Jüttner *et al.* (2003, p. 200) defined it as "a variation in the distribution of possible supply chain outcomes, their likelihood, and their subjective value."

In SC management, several publications have shared the initial view of risk as potential danger, damage, loss, injury or any other undesired consequences, which corresponds best to SC business reality. Following this, Wagner and Bode (2008, p. 308), applying contingency theory and strategic management, suggested extending the scope of risk to mean:

> […] high organizational efficiency and performance results when firms consider the context in which strategy is crafted and implemented.

Considering this, firms must match their structure to their context and environment, i.e. forces outside the decision-maker's control. If this "fit" is not reached, "opportunities are lost, costs rise, and the maintenance of the organization is threatened" (Child, 1972, p. 8). Confirming these statements, Jüttner (2005) then expanded the scope of risk from activities/processes of a firm, to include the SC flow, i.e. from the original suppliers to the delivery of the final product for the end-user.

A more scientific definition of risk was provided by the Warren (1992) as "[…] the probability that a particular adverse event occurs during a stated period of time, or results from a particular challenge. As a probability in the sense of statistical theory, risk obeys all the formal laws of combining probabilities." Subsequent authors have gone on to develop this scientific perspective of risk, typically Mitchell (1995) who defined risk as "[…] the probability of loss and the significance of that loss to the organisation or individual." The author expressed this idea as a formula to evaluate the probability of loss and the

significance of the loss for an event n:

$$\text{Risk}_n = \text{Probability}(\text{loss}_n) \times \text{Degree of impact}(\text{loss}_n)$$

By considering the above, Table I classifies risks into two criteria: context (SC flows) and probability.

After documenting 169 journal articles published in the SC risk literature between 2003 and 2016 (Figure 1), we were able to determine that the risks described in Table I have indeed received a great deal of attention. Each risk has different attributes, resulting in the various impacts on SC performance that will be discussed in the following section.

2.1 Supply risk

Supply risk results from disruptions emerging from "upstream" activities in the SC (Zsidisin and Ellram, 2003). Here, firms are faced with the risks related to suppliers, e.g. supplier bankruptcy, price fluctuations and/or unstable quality and quantity of inputs (Xie *et al.*, 2011; Chopra and Sodhi, 2012; Ketikidis *et al.*, 2006; Zsidisin and Ellram, 2003; Cucchiella and Gastaldi, 2006). These risks can trigger failures in delivering inbound goods/services to the purchasing firm and subsequently throughout the downstream SC (Wu *et al.*, 2006). Take the example of UPF-Thompson, the supplier of the chassis frames for Land Rover's award-winning SUV Discovery Sport, who filed for bankruptcy in December 2001. This abrupt situation caused the possibility of a nine-month production halt and the potential loss of 1,500 jobs for the Land Rover.

Mattel is another case in point. The corporation suffered an estimated $30 million worth of damage in 2007 when they had to recall 18 million toys because a supplier had ignored their guidelines not to use toxic chemicals in its production. Moreover, two years later the US Consumer Product Safety Commission sanctioned Mattel with a record $2.3 million fine. Boeing provides a further example when they experienced a supplier delivery failure of two critical parts, causing them an estimated loss of $2.6 billion. Hence, we propose the following hypothesis:

H1. Supply risk detrimentally affects SC performance.

2.2 Operational risk

Operational risk refers to the disruptions engendered by problems within the organizational boundaries of a firm that affect its ability to produce and supply goods/services, e.g. accidents, labor disputes or changes in design and technology (Xie *et al.*, 2011; Tuncel and Alpan, 2010; Samvedi *et al.*, 2013; Wu *et al.*, 2006). Sweeney (2013) found that the majority of labor accidents

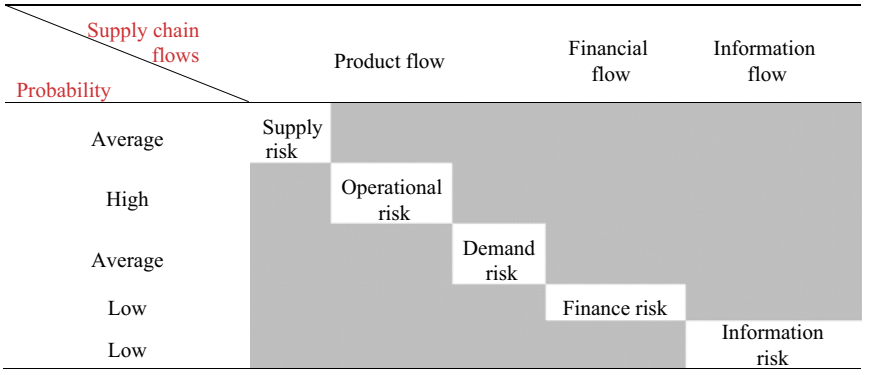
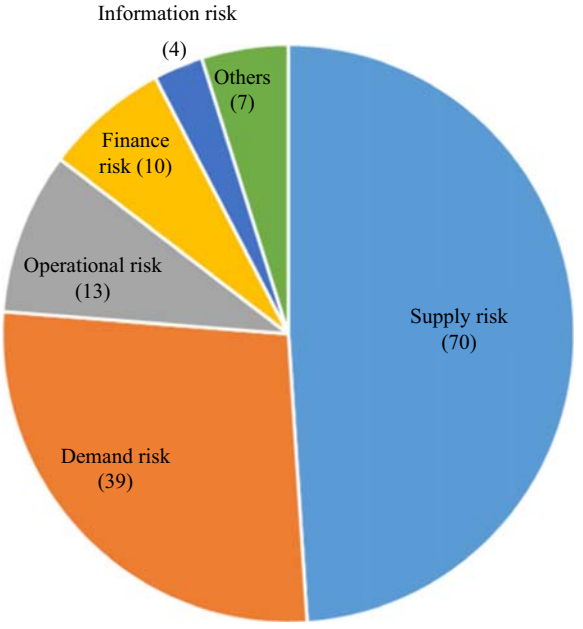


Table I.
Risk classification



Note: "Others" includes transportation, political and economic risk, and natural disasters

Figure 1.
Supply chain risks

resulting in employees taking more than three days off work – or affecting their ability to perform their usual duties over this period – were caused by handling accidents. Although some work accidents have minor effects, statistics from the UK Government's Health and Safety Executive revealed that due to occupational illness or personal injury more than 27 million working days were lost between 2011 and 2012, implying that these incidents can have serious repercussions. In 2002, fewer than 100 workers in a longshoreman's union strike disrupted operating activities at West Coast ports in the USA. As a consequence, it took six months for some containers to be delivered and schedules to return to normal.

Design and technological changes lead to increases in project costs as well as disrupt operating activities, thus resulting in a decrease in expected returns on investments (Kim and Chavas, 2003; Williams *et al.*, 1995). An example that illustrates this is the Mitsubishi Aircraft Corp. who, in January 2017, delayed the delivery of the new Mitsubishi Regional Jet for a fifth time, causing shares to drop 2.7 percent and extending their losses for 2017 to 20 percent. The jetliner, which seats 70-90 passengers, is designed for short-to-medium-haul flights and is expected to consume 20 percent less fuel than the similarly sized aircraft. Experts believed that any subsequent design changes could force Mitsubishi Aircraft to review production plans, leading to a substantial delay in the plane's delivery, even though manufacturing operations had already started. Hence, we propose the following hypothesis:

H2. Operational risk detrimentally affects SC performance.

2.3 Demand risk

Demand risk is concerned with "downstream" activities in the SC (Fleischhacker and Fok, 2015). This type of risk refers to customer bankruptcy, demand variability, high market competition or customer fragmentation (Manuj and Mentzer, 2008; Tuncel and Alpan, 2010; Gaudenzi and

Borghesi, 2006; Cucchiella and Gastaldi, 2006). These risks, when they occur, mean firms in the supply network are unable to forecast real market demands. Costs overrun, and revenue and profits fall as a result (Fleischhacker and Fok, 2015). Zsidisin and Ellram (2003) indicated that rapid changes in customer expectations increase product costs. Likewise, demand variability has a deteriorating effect on stochastic inventory systems (Jemaïemaı Karaesmen, 2005). For instance, in 2001 Cisco Systems Inc. reported a $2.25 billion inventory write-off due to a lack of communication with its downstream SC partners. Xu *et al.* (2010) asserted that demand uncertainty is an important factor for optimal decisions and expected profit. Therefore, we propose the following hypothesis:

H3. Demand risk detrimentally affects SC performance.

2.4 Finance risk

Finance risk deals with the changes in financial markets, e.g. inflation, interest rate levels, currency fluctuations and stakeholder requests (Manuj and Mentzer, 2008; Trkman and McCormack, 2009; Hahn and Kuhn, 2012), causing potential losses in the SC (Manuj and Mentzer, 2008). For instance, inflation engenders continuously increased prices that irritate consumers who blame the producers. Firms try to avoid raising their prices and to do so they lock material costs with long-term contracts, which hurts their suppliers. Moreover, companies that wish to plan ahead, encounter difficulties in the presence of uncertainty. They may, for instance, encounter problems with budgeting since they are unsure about costs.

Mitra *et al.* (2013) argued that as interest rates increase, banks charge more for business loans, resulting in reducing the ability of customers to buy products and services. This phenomenon can provoke price fluctuations in supply activities (Lee *et al.*, 2016).

Furthermore, currency fluctuations have various effects on output growth and price which are particularly true for multinational companies or foreign partners (Manuj and Mentzer, 2008). Yeo and Tiong (2000) suggested considering stakeholder requests as a finance risk. Stakeholders influence particular dimensions and typically have a strong voice in a firm's direction. For instance, they may have concerns about the daily activities of the business or be able to vote on critical decisions that affect SC operations. Thus, we propose the following hypothesis:

H4. Finance risk detrimentally affects SC performance.

2.5 Information risk

Information risk refers to distorted information, communication breakdown within the project team, information infrastructure complications and/or information leaks (Xie *et al.*, 2011; Chopra and Sodhi, 2012; Handfield and Nichols, 2002; Huong Tran *et al.*, 2016; Cucchiella and Gastaldi, 2006). Lack of information or distorted information passed through the SC can cause significant issues including, but not limited to, misguided capacity plans, missed production schedules, excessive inventory investment, ineffective transportation, poor customer service and lost revenues (Lee *et al.*, 2004). These are not deliberate attempts to sabotage the performance of fellow SC members, but rather distorted information throughout the SC having a bullwhip effect (Handfield and Nichols, 2002). A customer information leak by a systems engineer at Benesse, a Japan-based company which focuses on correspondence education and publishing, not only led to second quarter (2015) consolidated revenue being down 7 percent from the same period of the previous fiscal year, but also to an 88 percent decrease in operating profit and a loss of 280,000 customers (Ishii and Komukai, 2016). As such, we propose the following hypothesis:

H5. Information risk detrimentally affects SC performance.

3. Manufacturing-oriented firms and service-oriented firms

3.1 Operand resources and operant resources

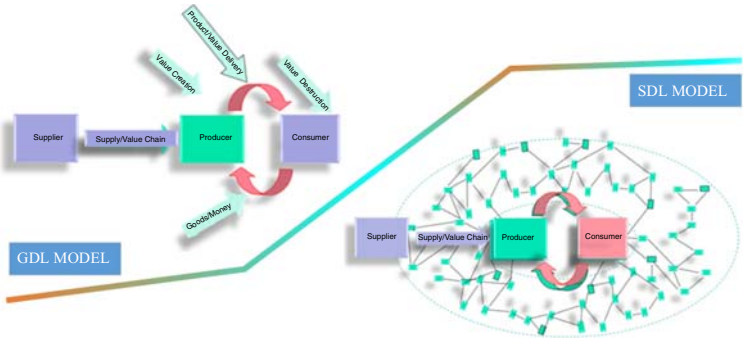
Resources in the world are limited (Ponting, 1991). With continued geometric population growth, in the near future, resources will soon run out of (Malthus, 1888). Resources referred to here can be land, minerals, animal and plant life, etc., i.e. natural resources. Constantin and Lusch (1994) defined these resources as operand resources on which an operation or act is performed to produce an effect. Malthus (1888) stated that these resources are essentially "static stuffs" and to be captured as a competitive advantage.

Vargo and Lusch (2004) argued that resources should be considered not only as "static stuffs," but also as intangible and dynamic functions of human ingenuity and appraisal, e.g. skills and knowledge. From this viewpoint, resources known as operant resources, that are not static or fixed but are invisible and intangible, are employed to act upon operand resources (Constantin and Lusch, 1994).

3.2 GDL and SDL

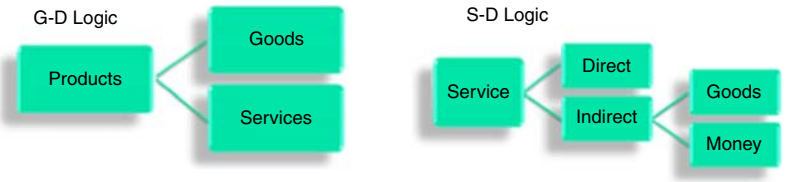
People exchange for goods that serve primarily as operand resources (Vargo and Lusch, 2004). Economic exchange is fundamentally concerned with units of outputs (tangibility) which are embedded with value during the manufacturing process (Capon and Glazer, 1987). Firms supporting this point of view (GDL), here called manufacturing-oriented firms, have production factors (largely operand resources) and aim to convert their operand resources into outputs at a low cost. Thus, standardization, traits of manufactured outputs, the separation of production and consumption and non-perishability are normative qualities (Zeithaml *et al.*, 1985). The value embedded in the operand resource is determined by the manufacturing-oriented firms throughout the exchange in the production processes and generally among the members in the SC, i.e. "value-in-exchange." In other words, value is added before use and concentrated more into exchanges between suppliers and manufacturing-oriented firms, i.e. SC management (Figure 2). At these firms, moreover, services are treated as "an immaterial product/residual/add-on," i.e. a kind of intangible goods, and addressed to enhancing the value of the goods in question (Figure 3) (see Fisk *et al.*, 1993).

Conversely, SDL considers service as a process rather than an add-on of output (Vargo and Lusch, 2004). All economic exchange represents both collaborative value creation and partially derived demand, i.e. demand chain management (Sengupta *et al.*, 2006, p. 13). Service-oriented firms do not make and sell units of output, but rather produce customized services for customers (Sengupta *et al.*, 2006, p. 13). Scholars supporting SDL



Source: Adapted from Stephen Vargo's presentation "Transforming business models with technology and innovations" at the Frontiers in Service Conference, Bergen, Norway, June 26, 2016

Figure 2.
GDL and SDL models



Source: Adapted from Stephen Vargo and Robert Lusch's presentation "Service-Dominant Logic: An Evolution or Revolution in Marketing Theory and Practice?" at the John Molson School of Business, Concordia University Montreal, October 20, 2011

Figure 3.
Products and services

realized that customers are not buying output, but the service capabilities of that output (Phillips *et al.*, 1999), thus, firms should develop alliances and partnerships with customers (Bucklin and Bucklin, 1970; Sengupta *et al.*, 2006).

Moreover, while GDL implies that production is a process of embedded value and destruction of that value will occur upon consumption (Figure 2), in contrast, an assumption of SDL is that:

> […] one party does not produce value while the other consumes/ destroys value (Vargo and Lusch, 2004; Vargo and Lusch, 2008, p. 257).

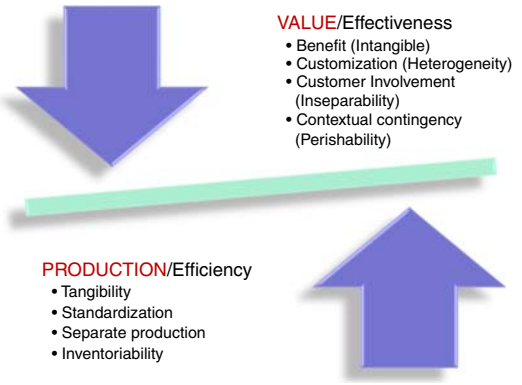
This is a value co-creation process, with each party bringing its own resource accessibility and integrability into that process. In this theory, the customer is primarily an operant resource, a co-producer of service. Value results from the beneficial application of operant resources and determined by the consumer on the basis of "value in use." Vargo and Lusch (2004) argued that in either case – service provided directly or through goods – the knowledge and skills of service-oriented firms are essential sources of value creation; instead of the goods which are only sometimes used to convey them. Hence, from the viewpoint of this SDL, goods are "appliances" for service provision, i.e. conveyors of competences (Figure 3).

Another distinction associated with efficiency vs effectiveness (Figure 4) (Vargo and Lusch (2008, p. 257) suppose a goods model centered toward the primacy of efficiency. Manufacturing-oriented companies find ways to provide efficiency that requires production activities to be isolated from the customer and results in standardized, inventoriable goods. Meanwhile, the fathers of SDL, Vargo and Lusch (2008), state that efficiency and effectiveness can be seen as complementary and described the relationship between these two concepts as thus:

> […] effectiveness is necessary before efficiency has relevance but efficiency is often both a component (buyer's perspective) of effectiveness and also necessary for long-term effectiveness (seller's perspective). Thus, effectiveness can be seen as a path to efficiency.

McQuail (1994), the author of "mass communication," asserted that most manufacturing-oriented firm communication with the market is one way, i.e. mass communication. Information flows from the firm into the market or to segments of markets. A service-centered view of exchange, however, infers that customer demand increasingly specializes and turns to a firm's domestic market relationships for services outside that firm's competences. Thus, a communication process characterized by dialog, by asking and answering questions, is imperative (Prahalad and Hamel, 2006).

Duncan and Moriarty (1998, p. 3) determined the differences between manufacturing- and service-oriented firms in that one is a functional, mechanistic, production-oriented model, while the other is a more humanistic, relationship-based model. Lavastre *et al.* (2014, p. 3, 385)



Source: Adapted from Stephen Vargo and Robert Lusch's presentation "Service-Dominant Logic: An Evolution or Revolution in Marketing Theory and Practice?" at the John Molson School of Business, Concordia University Montreal, October 20, 2011

Figure 4.
Efficiency and effectiveness

supposed that at firms with different characteristics, risk behaviors and their impact on SC performance also vary. With empirical evidence from 300 Australian companies, Subramaniam *et al.* (2009) also determined that company characteristics have a significant association with an organization's risk management strategies, policies and processes. Empirical data from US interstate motor carriers, also indicated that characteristics of firms can be a reliable predictor of accident risk (Moses and Savage, 1994, p. 173). Hence, we propose the following hypothesis:

H6. For the impact of risks on SC performance, a distinction can be made between manufacturing- and service-oriented firms.

4. Research methodology

4.1 Large-scale data collection

Data used throughout this study come from a large-scale survey which is part of a Japanese Government initiative to promote sustainable socio-economic development in the Association of Southeast Asian Nations. A total of 3,601 companies in the construction sector in Vietnam responded to the survey. This sector was chosen because it plays a vital role in any economy in terms of providing shelter, infrastructure, employment, etc. However, compared to many other industries, it is inherently risky because of its unique characteristics such as its manufacturing facilities or plants having to be located on the construction sites themselves, its long timeframes, complicated processes, unpredictable environments, financial intensity, complex relationships and dynamic organizational structures. As a result, work-related accidents are commonplace and a reputation for being unable to resolve issues develops. Furthermore, many projects fail to meet deadlines and/or costs and/or quality targets. Typically, a 10 percent contingency is added to the total project cost to accommodate for unforeseen circumstances. This is precisely why we selected the construction sector to validate our conceptual framework.

Target respondents to the survey were managers, co-ordinators, etc., who have information and experience in logistics and SC management. A link to the questionnaire was sent to the firms via their e-mail addresses. Three follow-up e-mails were subsequently

generated and, as a result, 283 usable responses were received. Table II describes the sample characteristics of the survey.

Non-response bias was assessed to test the difference in items between early and late respondents (Armstrong and Overton, 1977). The results showed that no significant differences on the average scores of all observed items were found (internal confidence of 99 percent), which indicates the absence of non-response bias.

4.2 Questionnaire development

4.2.1 SC risks. First, based on an extensive literature review of SC risk management, the measures of the SC risks were proposed (Table III). Then a preliminary questionnaire was drafted. Next, structural interviews with academicians were conducted and their comments were recorded and analyzed before implementing some improvements in the measurement scales. Following this, eleven managers participated in the Q-sort analysis to preliminarily assess the unidimensionality, reliability and validity of the research concepts. Hence, the final version of the questionnaire was developed.

The respondents were asked to assess the severity of SC disruptions and to specify how their SC had been affected during last five years by these risks. To determine the different attitudes of the respondents, five-point Likert-type items were employed with a score of 1 indicating "strongly disagree" to 5 "strongly agree."

Traditional psychometric approaches were used to evaluate the validity and reliability of each scale (Hair *et al.*, 1995). In particular, convergent validity was assessed using principal component factor analysis with varimax rotation to explore the underlying structure of the research concepts. Reliability was checked by Cronbach's α and corrected item-total correlation. The results of the factor analysis and reliability evaluation have been included in the Table AI. Accordingly, after deleting some items that did not reach threshold values, all items meet established standards for convergent validity, i.e. all items load on unique components with factor loadings larger than 0.5. Moreover, all corrected item-total

Firm profile	Freq.	Firm profile	Freq. Manufacturing-oriented firms	Freq. Service-oriented firms
Operation fields		*Years of business*		
Manufacturing-oriented firms		< 5 years	10	31
Building material manufacturing (sand, stone, additive, etc.)	42	5-10 years	29	65
Concrete production	49	10-20 years	33	70
Service-oriented firms		20-30 years	18	17
Building material distribution	53	30-40 years	1	6
Contractors	99	40-50 years	0	3
Design (architecture and construction)	37	*Authorized capital*		
Transportation	3	< 20 billion VND	9	39
		20-100 billion VND	20	49
		> 100 billion VND	62	104
		Full-time employees		
		Less than 10	1	8
		10-200	23	99
		200-300	25	44
		More than 300	42	41

Table II. Sample characteristics

VND: Vietnamese Dong

Supply chain risk types				
Supply	Operations	Demand	Finance	Information
Risk factors				
Supplier bankruptcy	Design changes	Market changes	Exchange rate	Communication breakdown with project team
Supplier opportunism	Employee accidents	Demand uncertainty	Currency fluctuations	Information infrastructure breakdown
Lack of supplier visibility	Product obsolescence	High competition in the market	Interest rate levels	System integration or extensive systems networking
Selection of wrong partner	Technological changes	Customer fragmentation	Inflation	E-commerce
Lack of integration with suppliers	Labor disputes/ strikes	Inaccurate demand forecasts	Wage rate shifts	Information delays
Failure to make delivery requirements	Insufficient maintenance	Low in-house production	Financial strength of customers	internet security
Inability to handle volume demand changes	Warehouse and production disruption	Deficient or missing customer relation management function	Stakeholders (request late changes, new stakeholders, etc.)	Bullwhip effect or information distortion
Inability to meet quality requirements		Customer dependency	Credit risk	
Price fluctuations		Order fulfilment errors		
Transportation breakdowns				
Supply responsiveness				
Supplier dependency				
Authors				
Xie *et al.* (2011), Chopra and Sodhi (2012), Ketikidis *et al.* (2006), Zsidisin and Ellram (2003)	Xie *et al.* (2011), Samvedi *et al.* (2013), Tuncel and Alpan (2010), Wu *et al.* (2006)	Manuj and Mentzer (2008), Gaudenzi and Borghesi (2006), Tuncel and Alpan (2010)	Manuj and Mentzer (2008), Trkman and McCormack (2009), Hahn and Kuhn (2012)	Xie *et al.* (2011), Chopra and Sodhi (2012), Handfield and Nichols (2002)

Table III.
SC risk measures

correlation are above 0.504, and Cronbach's α coefficients range from 0.769 to 0.837, implying the reliability of the constructs.

Table IV describes the χ^2 differences between the research concepts used to test discriminant validity (Garver and Mentzer, 1999). From the five research concepts, 15 pairs

	SR	OR	DR	FR	IR
SR	1				
OR	74.797	1			
DR	146.596	141.744	1		
FR	128.254	116.847	185.402	1	
IR	70.349	54.27	142.566	96.166	1

Note: All χ^2 differences were significant at 0.001

Table IV.
χ^2 differences between research concepts

are compared using two models for each pair. The first comparison is to allow free correlation between the two constructs, and the second is to fix the correlation between the two constructs at 1.0. The results indicated that at $p < 0.001$ all the differences between the research concepts are significant. Thus, we can conclude that they are all discriminant (Garver and Mentzer, 1999). Above all, the measures possessed sufficient validity and reliability to proceed with hypotheses testing.

Following this, structural equation modeling (SEM) analysis able to simultaneously calculate the effect of different risks on SC performance was used to validate research hypotheses. The similarities and differences between manufacturing-oriented and service-oriented firms were then compared using multiple-group analysis. This method is a non-parametric significant test for the difference of group-specific results. At a 5 percent probability of error, a result is significant if the *p*-value is smaller than 0.05 or larger than 0.95 for a certain difference of group-specific path coefficients (Henseler *et al.*, 2009).

4.2.2 SC performance. Financial indicators, e.g. cost, return on investment, growth, etc., are commonly recognized as key performance indicators with which to assess SC efficiency (Quang *et al.*, 2016). These indicators are the main objectives in SC management because minimizing cost and waste results in a higher performing SC. However, cost tends to be historical and does not demonstrate the current situation of the business environment nor prospects for future performance and return on investment and growth become meaningless when comparing enterprises in different sectors (Quang *et al.*, 2016). For example, an ineffective firm operating in the software industry – a high-growth sector – will have higher revenue growth/ profitability growth, etc., than an effective firm working in the apparel industry.

Evidently, financial indicators still play an important role. Nevertheless, to pave the way for a comprehensive performance scale, they need to be balanced with more contemporary, intangible and strategic-oriented measures (Quang *et al.*, 2016).

Developed by Kaplan and Norton (1992), the balanced scorecard (BSC) model identifies the limitations traditional performance measurements have and translates a SC's strategy into performance objectives, concentrating particularly on intangible assets such as the innovation value chain, employee skills and knowledge levels, customer and supplier relationships, etc. This new approach shifts from the conventional focus on physical assets to an emphasis on both physical and intangible resources in a SC for long-term corporate development. A BSC has four balanced perspectives, namely, customer, financial, internal processes and innovation and learning (Kaplan and Norton, 1992).

This study defines a set of indicators for SC performance based on these four BSC aspects (Table V). Accordingly, five critical dimensions are proposed: innovation and learning, supplier performance, internal business, customer service and finance.

5. Results

Table VI presents the validated results of the hypotheses proposed in this study. Accordingly, the impacts of supply, operational and demand risks on SC performance are supported. Conversely, no relationships are found between finance risk and SC performance or information risk and SC performance. Moreover, these five SC risks explain 87.1 percent of the variance in SC performance.

Additionally, the results indicate that, between the two groups being compared, there is a difference of the risk behaviors' impact (significance $p < 0.001$). Table VII shows the comparison between the manufacturing- and service-oriented firms.

We can see that (apart from finance risk not being found to have an impact on SC performance in either group) operational and demand risks in the manufacturing firm group

Supplier performance	Internal business	Innovation and learning	Customer service	Finance
Supply chain performance indicators				
Reliability	Amount of production waste	Number of new products developed per year	Delivery timeliness	Market share growth
Response time	Costs of inventory management	Workforce flexibility	Percentage of "perfect orders" delivered	Return on Investments (ROI)
Delays in supply activities	Workforce productivity		Product value perceived by the customer	Delayed payment
	Delays in operating activities		Product/ Service quality	
	Information delays		Response time to customer queries	
	Delays in distribution activities			

Authors
Wang *et al.* (2009), Taticchi *et al.* (2010), Papakiriakopoulos and Pramatari (2010), Sarkis *et al.* (2010), Ketikidis *et al.* (2006)

Table V.
Supply chain performance indicators

Hypotheses	Relationships	Standardized estimate	*p*	Result
H1	Supply risk → SCP	−0.316	0.009	Supported
H2	Operational risk → SCP	−0.447	0.009	Supported
H3	Demand risk → SCP	−0.249	0.002	Supported
H4	Finance risk → SCP	0.062	0.322	Not supported
H5	Information risk → SCP	−0.144	0.188	Not supported

Notes: Goodness of fit: $\chi^2/df = 1.899$; CFI = 0.904; RMSEA = 0.056; $R^2 = 0.871$

Table VI.
SEM results

Relationships	Manufacturing-oriented firms	Service-oriented firms
Supply risk → SCP	None	−0.512**
Operational risk → SCP	−0.93***	None
Demand risk → SCP	−0.477***	None
Finance risk → SCP	None	None
Information risk → SCP	0.474**	−0.262*
R^2	88.3%	85.6%

Notes: *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table VII.
Comparison between manufacturing and service-oriented firms

do have a strong and negative effect on SC performance. Meanwhile, in the service-oriented firm group, it is supply risk that detrimentally affects the SC performance.

Another interesting result relates to information risk, where a negative influence on SC performance was found for the service group, but was found to have a positive impact on the manufacturing group.

Finally, R^2 that explains for percent variance in SC performance in the manufacturing-oriented firms (88.3 percent) is higher than that in the service-oriented firms (85.6 percent).

6. Discussion

Empirical evidence from the 283 construction firms notably sheds light on the relationship between the five critical risks in SC and SC performance. These risks do not affect SC performance separately, but rather simultaneously. In a very serious situation, the five risks occur at the same time and so can explain the 87.1 percent variance in SC performance. This is a significant percentage because SC performance depends not only on risks, but also on other external factors such as political policies, the economy, the external environment, etc. In other words, even with the same external factors, firms who can manage the SC risks well are able to obtain sustainable competitive advantages.

Moreover, the impact of risks on SC performance varies between manufacturing- and service-oriented firms. In the manufacturing group, the five critical risks accounted for an 88.3 percent variance in SC performance, whereas for the service group this was 85.6 percent, implying that risks existing in manufacturing-oriented firms have a greater effect on SC performance than those in service-oriented firms. Particularly, there is a significant relationship between supply, operational and demand risks and SC performance. These risks pertaining to product flow are ordinary workday problems (Rice and Caniato, 2003), therefore they are highly likely to occur and directly affect SC performance (Thun and Hoenig, 2011). Wagner and Bode (2008) categorized these types of risk as "contextual variables" that must necessarily be factored into strategic SC decisions.

Conversely, finance and information risks bear no relationship to SC performance. In the SC network, finance and information are "infrastructure" elements that aim to ensure the healthy functioning of the chain (Ho *et al.*, 2015). Any disruptions relating to these elements can lead to serious problems for processes in the SC – especially supply, manufacturing and downstream activities (Ho *et al.*, 2015). Thus, although the direct impact of these risks on SC performance is not significant, they might affect other risks, thereby, having indirect effects on SC performance. Future research should examine the interrelationship SC risks that have to be able to demonstrate the indirect effects SC risks have on SC performance and consolidate this statement as well.

Figure 5 describes the differences between manufacturing- and service-oriented firms that can be explained by the theory of GDL and SDL. As mentioned above, manufacturing-oriented firms manage their SC from upstream to downstream, i.e. SC management (Figure 6). Values come from exchanges between members in the chain, especially between suppliers and manufacturers, and are termed as the value-in-exchange (Sengupta *et al.*, 2006). Thus, manufacturing-oriented firms will focus more on supply-related activities, i.e. make efforts/provide resources to minimize this type of risk. Moreover, manufacturing-oriented firm inputs are "visible" (Morris and Johnston, 1987), explaining why the impact of supply risk on SC performance is not found in this group.

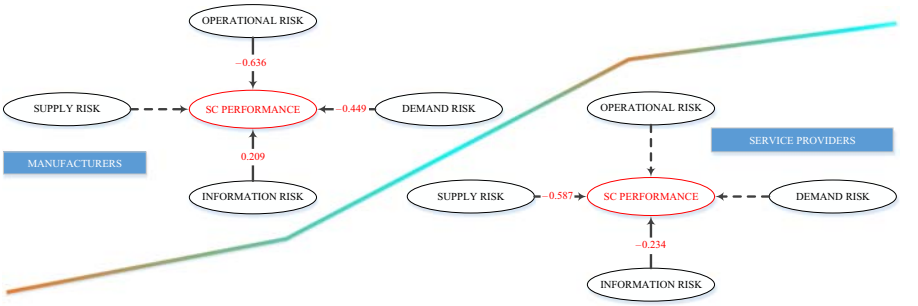
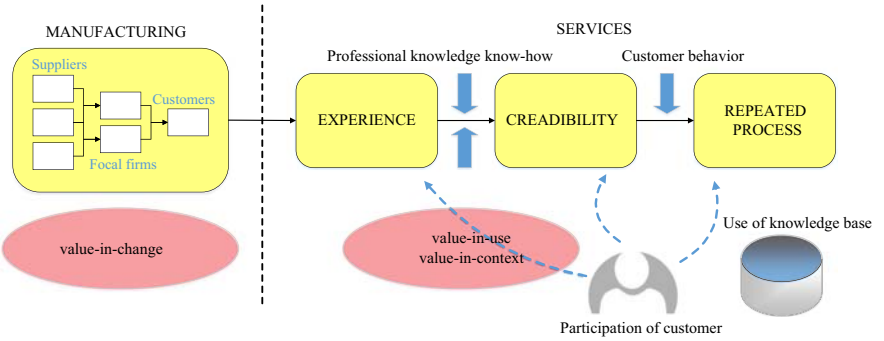


Figure 5.
The impact of SC risks on SC performance in the two groups compared



Source: Adapted from a research proposal from the project entitled "An Empirical Study on Services Value Chain based on the Experiential and Credibility Values"

Figure 6. Supply chain management and demand chain management

On the contrary, service-oriented firm inputs are "vague" (Morris and Johnston, 1987). Their management starts from meeting customer demand, i.e. demand chain management, a core activity of service-oriented firms (Sengupta *et al.*, 2006; Vargo and Lusch, 2008). In this type of business, moreover, production and consumption are concurrent. Thus, values will be created through the consumption processes and dependent on the context of providing services (operational processes) known as value-in use/value-in-context (Figure 6). Demand- and operational-related activities, therefore, receive much attention.

Moreover, service firm customers demand a high level of consistency. Once they have accepted a product/company, it is rare for them to change to others. Meanwhile, manufacturing firm products are tangible and have a high level of standardization. Thus, the barriers to conversion are low, customers easily change to using products from the competition. In many cases, a customer may well use one product today, but ask to use another company's product tomorrow (Solomon *et al.*, 2012). Hence, for manufacturing-oriented firms it is hard to control demand risk.

Another interesting result relates to the information risk that can increase SC effectiveness in the manufacturing group but have a negative effect on SC performance in the service-oriented group. This finding supports the argument of Jüttner *et al.* (2003) implying that risks are not only losses because, in some cases, they can present opportunities for companies. Evidently, information risk, when it incurs, reduces the quantity and quality of information reaching the other members of the chain, thus decreasing SC performance as the results from the service group demonstrate. In the operating processes, customer needs, information of processes, service, etc., need to be understood by all the employees. The more information shared, the greater the service quality is improved (Lee *et al.*, 2004). However, this argument is not completely accurate for manufacturing-oriented firms. Sometimes, too much information will disrupt processes as employees are not clear on exactly what they need to do, how to operate, etc. This is particularly true in developing countries where a large amount of human capital is required, but the quality of labor is still low as the majority of them are low-skilled workers. This perhaps can explain that when information risk occurs, performance of the manufacturing SC is increased. Gardner and Cooper (2003) agreed with this and stated that:

> […] Firms must be careful about providing more data than channel partners or firms need for their contributions to the supply chain, inadvertently giving away competitive information. However, brand share data concerning suppliers, which is not as easily known, can cause channel conflict. Including retail share data in a distributed map, while sensitive, may not be a critical risk. The same data in an environment without the alternative data sources could be very detrimental.

Table VIII presents the level of severity the risk factors have to significantly affect SC performance. Generally, risk factors are mostly greater than 3 – the average level, particularly, in the service group where price fluctuations and distorted information are the ones that have the greatest degree of danger in the corresponding risk type. For the manufacturing group, accidents, customer bankruptcy and distorted information need to receive more attention. Hence, some managerial implications are discussed in the effort to mitigate these SC risks.

Chopra and Sodhi (2012) recommended coping with price fluctuations by building inventory, having multiple sources of supply or signing long-term contracts. For instance, in 2002 many companies selectively held inventories after learning of the impending dockworkers' strike in California. Consequently, when supply was disrupted, as predicted, losses were minimal. Stockpiling inventory is ideally used as a hedge against price fluctuations for commodity products with low holding costs and no danger of obsolescence.

Contracting redundant suppliers can be another good option, but only if firms can maintain the economies of scale. The global automobile manufacturer, Toyota, seeks out local economies of scale by single-sourcing at the plant level, but recruiting redundant suppliers globally. Thus, a firm might be the sole supplier to a Toyota plant, it must keep prices down to rival for business across the entire Toyota network. Moreover, long-term contracts can keep price stable, but they can also badly reduce profits if prices for the contracted goods fall. One example of this comes from California where, a commitment signed by the mayor at the peak of its electricity crisis in 2001 forced the state to pay eight times more than the 2002 market price (Sodhi and Tang, 2012).

The US National Safety Council reported that human behavior was associated with 94 percent of all workplace injuries and illnesses (Loafman, 1996). This has revealed the importance of focusing on employee behavior as a critical element in achieving better safety standards. From this point of view, behavior-based safety (BBS) appears to be a promising method because of its two major strengths: a focus on employee behavior which

	Manufacturing-oriented firms	Service-oriented firms
SR		
Supplier bankruptcy		3.19[a]
Price fluctuations		3.40
Unstable quality of inputs		3.34
Unstable quantity of inputs		3.06
OR		
Design changes	3.04	
Technological changes	3.12	
Accidents	3.24	
Labor disputes	3.12	
DR		
Demand variability	3.43	
High competition in the market	3.40	
Customer bankruptcy	3.54	
Customer fragmentation	3.15	
IR		
Communication breakdown with project team	2.70	2.96
Information infrastructure breakdown	2.84	2.94
Distorted information	3.13	3.25

Notes: [a]Min = 1, Max = 5

Table VIII. The degree of danger of risk factors in the two groups

is claimed to be the main source of injuries and illnesses (McSween, 2003) and encouraging employee involvement in safety issues so that safety is not seen solely as the management's responsibility. The aim of BBS is to reinforce the importance for workers to behave safely as they carry out their activities. That is why a typical BBS intervention consists of basic safety training (antecedent), followed by a periodic observation and positive feedback (consequence) to enforce safe behavior (Guastello, 1993). Komaki *et al.* (1980) found that lost-time accidents per month were reduced from 3.0 to 0.4 during intervention, or an investigation by Fellner and Sulzer-Azaroff (1984) with 158 workers from 17 divisions of the paper mill found that injury rate decreased from 6.9 in pre-intervention to 4.9 during intervention.

Customer bankruptcy is an extremely serious situation which causes a huge disruption in the SC. Srinivasan and Kim (1988) suggested one way to avoid this is to evaluate the financial health of customers and identify clients who might become bankrupt. Firms can carefully monitor their clients' credit status by having each one complete a credit application and credit agreement. It is imperative to conduct a credit check on clients who place large orders (Gaudenzi and Borghesi, 2006). Battiston *et al.* (2007) encouraged firms to follow up with periodic credit checks, which many small businesses fail to do, in an aim to identify a customer may be heading for bankruptcy.

The last information risk – distorted information – is found to have the highest degree of danger in both groups. Information distortion gives the actors in the chain the wrong incentives and is the opposite of sound collaboration and communication within the chain (Handfield and Nichols, 2002; Huong Tran *et al.*, 2016). Machuca and Barajas (2004) suggested that companies need to adopt electronic data interchange (EDI) and share their information in a transparent way to improve their communication and reduce information distortion. The interchange of electronic data allows this information to be available from downstream to upstream in the SC and provides rapid transmission and sharing of accurate, reliable information throughout all the stages of the SC (Lee *et al.*, 2004). Information sharing through EDI, creates greater stability in orders placed with the factory and this will lead to more stable production levels which, in turn, leads to more efficient production planning, less need for expensive corrections and, hence, a reduction in cost for the SC (Machuca and Barajas, 2004). However, the quality and quantity of this shared information is essential to the success of the SC (Gardner and Cooper, 2003).

7. Conclusions

This research provides an extensive illustration of the relationship between SC risks and SC performance and clearly depicts that risks do not affect SC performance separately, but simultaneously. According to the results, when all of the five proposed risks happen in unison, they can explain an 87.1 percent variance in SC performance. It is worthwhile noting that the impact risks have on SC performance varies between manufacturing- and service-oriented firms. In fact, the risks occurring in manufacturing-oriented firms have stronger negative effects on SC performance than those in service-oriented firms do. Therefore, manufacturing-oriented firms should pay careful attention to operational and demand risks that adversely affect SC performance and "treat" information risk as an opportunity to improve SC performance. Service-oriented firms, on the other hand, must manage supply risks which can be attributed to a 51.2 percent variance in SC performance. Furthermore, service quality can be improved remarkably if information risk is well managed.

One of the "original contributions" of this study has been to use GDL and SDL theory to identify the different characteristics between the two groups being compared. This approach provides an insight into the differences between the two groups because the two types of business were classified based on resources, value, networks, effectiveness vs efficiency and communication. Future studies could apply this approach to their own

contexts to verify these results. In this work, finance risk having an impact on SC performance is not found. This risk is defined as an "infrastructure" factor that might indirectly affect SC performance throughout the other risks/factors. Thus, further research is needed to examine any mutual interaction between SC risks to consolidate this statement. Moreover, for a more comprehensive view, some risk factors from the external perspective of SC, e.g. natural disasters, political uncertainty, economic downturns, etc., also need to be added into the research model.

Finally, some practices, such as innovation or SC management, etc., that have positive effects on SC performance are still missing. A new approach could be to validate model the proposed here in terms of innovation and SC risk management practices, etc. This approach, i.e. integrating these factors and SC risks into the model, would not only be able to examine how innovation and SC management practices, etc., mitigate SC risks, but also draw up an extensive picture of risk management activities in the SC network. Discussions like these imply new directions for future research work.

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References

Armstrong, J.S. and Overton, T.S. (1977), "Estimating nonresponse bias in mail surveys", *Journal of Marketing Research*, Vol. 14 No. 3, pp. 396-402.

Battiston, S., Gatti, D.D., Gallegati, M., Greenwald, B. and Stiglitz, J.E. (2007), "Credit chains and bankruptcy propagation in production networks", *Journal of Economic Dynamics and Control*, Vol. 31 No. 6, pp. 2061-2084.

Bucklin, L.P. and Bucklin, L.P. (1970), *Vertical Marketing Systems*, Scott Foresman, Glenview, IL.

Capon, N. and Glazer, R. (1987), "Marketing and technology: a strategic coalignment", *The Journal of Marketing*, Vol. 51 No. 3, pp. 1-14.

Child, J. (1972), "Organizational structure, environment and performance: the role of strategic choice", *Sociology*, Vol. 6 No. 1, pp. 1-22.

Chopra, S. and Sodhi, M. (2012), "Managing risk to avoid supply-chain breakdown", *MIT Sloan Management Review*, Vol. 46 No. 1, pp. 53-61.

Constantin, J.A. and Lusch, R.F. (1994), *Understanding Resource Management*, The Planning Forum, Oxford, OH.

Cucchiella, F. and Gastaldi, M. (2006), "Risk management in supply chain: a real option approach", *Journal of Manufacturing Technology Management*, Vol. 17 No. 6, pp. 700-720.

Cudney, E. and Elrod, C. (2011), "A comparative analysis of integrating lean concepts into supply chain management in manufacturing and service industries", *International Journal of Lean Six Sigma*, Vol. 2 No. 1, pp. 5-22.

Duncan, T. and Moriarty, S.E. (1998), "A communication-based marketing model for managing relationships", *The Journal of Marketing*, pp. 1-13.

Ellis, S.C., Henry, R.M. and Shockley, J. (2010), "Buyer perceptions of supply disruption risk: a behavioral view and empirical assessment", *Journal of Operations Management*, Vol. 28 No. 1, pp. 34-46.

Fellner, D.J. and Sulzer-Azaroff, B. (1984), "Increasing industrial safety practices and conditions through posted feedback", *Journal of Safety Research*, Vol. 15 No. 1, pp. 7-21.

Fisk, R.P., Brown, S.W. and Bitner, M.J. (1993), "Tracking the evolution of the services marketing literature", *Journal of Retailing*, Vol. 69 No. 1, pp. 61-103.

Fleischhacker, A.J. and Fok, P.-W. (2015), "On the relationship between entropy, demand uncertainty, and expected loss", *European Journal of Operational Research*, Vol. 245 No. 2, pp. 623-628.

Gardner, J.T. and Cooper, M.C. (2003), "Strategic supply chain mapping approaches", *Journal of Business Logistics*, Vol. 24 No. 2, pp. 37-64.

Garver, M.S. and Mentzer, J.T. (1999), "Logistics research methods: employing structural equation modeling to test for construct validity", *Journal of Business Logistics*, Vol. 20 No. 1, pp. 33-57.

Gaudenzi, B. and Borghesi, A. (2006), "Managing risks in the supply chain using the AHP method", *The International Journal of Logistics Management*, Vol. 17 No. 1, pp. 114-136.

Guastello, S.J. (1993), "Do we really know how well our occupational accident prevention programs work?", *Safety Science*, Vol. 16 No. 3, pp. 445-463.

Hahn, G.J. and Kuhn, H. (2012), "Value-based performance and risk management in supply chains: a robust optimization approach", *International Journal of Production Economics*, Vol. 139 No. 1, pp. 135-144.

Hair, J.F., Anderson, R.E., Tatham, R.L. and Black, W.C. (1995), *Multivariate Data Analysis with Readings*, 4th ed., Prentice Hall, Englewood Cliffs, NJ.

Handfield, R.B. and Nichols, E.L. (2002), *Supply Chain Redesign: Transforming Supply Chains into Integrated Value Systems*, FT Press, NJ.

Henseler, J., Ringle, C.M. and Sinkovics, R.R. (2009), "The use of partial least squares path modeling in international marketing", in Zou, S. (Ed.), *New Challenges to International Marketing*, Emerald Group Publishing Limited, Bingley, pp. 277-319.

Ho, W., Zheng, T., Yildiz, H. and Talluri, S. (2015), "Supply chain risk management: a literature review", *International Journal of Production Research*, Vol. 53 No. 16, pp. 5031-5069.

Huong Tran, T.T., Childerhouse, P., Childerhouse, P., Deakins, E. and Deakins, E. (2016), "Supply chain information sharing: challenges and risk mitigation strategies", *Journal of Manufacturing Technology Management*, Vol. 27 No. 8, pp. 1102-1126.

Ishii, K. and Komukai, T. (2016), "A comparative legal study on data breaches in Japan, the US, and the UK", paper presented at the IFIP International Conference on Human Choice and Computers, Salford.

Jemaï, Z. and Karaesmen, F. (2005), "The influence of demand variability on the performance of a make-to-stock queue", *European Journal of Operational Research*, Vol. 164 No. 1, pp. 195-205.

Jüttner, U. (2005), "Supply chain risk management: understanding the business requirements from a practitioner perspective", *The International Journal of Logistics Management*, Vol. 16 No. 1, pp. 120-141.

Jüttner, U., Peck, H. and Christopher, M. (2003), "Supply chain risk management: outlining an agenda for future research", *International Journal of Logistics: Research and Applications*, Vol. 6 No. 4, pp. 197-210.

Kaplan, R.S. and Norton, D. (1992), "The balanced scorecard: measures that drive performance", *Harvard Business Review*, Vol. 70 No. 1, pp. 71-79.

Ketikidis, P.H., Lenny Koh, S., Gunasekaran, A., Cucchiella, F. and Gastaldi, M. (2006), "Risk management in supply chain: a real option approach", *Journal of Manufacturing Technology Management*, Vol. 17 No. 6, pp. 700-720.

Kim, K. and Chavas, J.P. (2003), "Technological change and risk management: an application to the economics of corn production", *Agricultural Economics*, Vol. 29 No. 2, pp. 125-142.

Komaki, J., Heinzmann, A.T. and Lawson, L. (1980), "Effect of training and feedback: component analysis of a behavioral safety program", *Journal of Applied Psychology*, Vol. 65 No. 3, pp. 261-270.

Kumar, S., Himes, J.K. and Kritzer, P.C. (2014), "Risk assessment and operational approaches to managing risk in global supply chains", *Journal of Manufacturing Technology Management*, Vol. 25 No. 6, pp. 873-890.

Lavastre, O., Gunasekaran, A. and Spalanzani, A. (2014), "Effect of firm characteristics, supplier relationships and techniques used on supply chain risk management (SCRM): an empirical investigation on French industrial firms", *International Journal of Production Research*, Vol. 52 No. 11, pp. 3381-3403.

Lee, H.L., Padmanabhan, V. and Whang, S. (2004), "Information distortion in a supply chain: the bullwhip effect", *Management Science*, Vol. 43 No. 4, pp. 546-558.

Lee, Y., Rösch, D. and Scheule, H. (2016), "Accuracy of mortgage portfolio risk forecasts during financial crises", *European Journal of Operational Research*, Vol. 249 No. 2, pp. 440-456.

Loafman, B. (1996), "Rescue from the safety plateau", *Performance Management Magazine*, Vol. 14 No. 3, pp. 3-10.

Lovelock, C. and Gummesson, E. (2004), "Whither services marketing? In search of a new paradigm and fresh perspectives", *Journal of Service Research*, Vol. 7 No. 1, pp. 20-41.

McQuail, D. (1994), *Mass Communication*, Sage, London.

McSween, T.E. (2003), *Values-Based Safety Process: Improving Your Safety Culture with Behavior-Based Safety*, John Wiley & Sons, Hoboken, NJ.

Machuca, J.A. and Barajas, R.P. (2004), "The impact of electronic data interchange on reducing bullwhip effect and supply chain inventory costs", *Transportation Research Part E: Logistics and Transportation Review*, Vol. 40 No. 3, pp. 209-228.

Malthus, T. (1798), *An Essay on the Principle of Population*, London.

Manuj, I. and Mentzer, J.T. (2008), "Global supply chain risk management strategies", *International Journal of Physical Distribution & Logistics Management*, Vol. 38 No. 3, pp. 192-223.

March, J.G. and Shapira, Z. (1987), "Managerial perspectives on risk and risk taking", *Management Science*, Vol. 33 No. 11, pp. 1404-1418.

Mitchell, V.W. (1995), "Organizational risk perception and reduction: a literature review", *British Journal of Management*, Vol. 6 No. 2, pp. 115-133.

Mitra, S., Date, P., Mamon, R. and Wang, I.-C. (2013), "Pricing and risk management of interest rate swaps", *European Journal of Operational Research*, Vol. 228 No. 1, pp. 102-111.

Morris, B. and Johnston, R. (1987), "Dealing with inherent variability: the difference between manufacturing and service?", *International Journal of Operations & Production Management*, Vol. 7 No. 4, pp. 13-22.

Moses, L.N. and Savage, I. (1994), "The effect of firm characteristics on truck accidents", *Accident Analysis & Prevention*, Vol. 26 No. 2, pp. 173-179.

Naldi, L., Nordqvist, M., Sjöberg, K. and Wiklund, J. (2007), "Entrepreneurial orientation, risk taking, and performance in family firms", *Family Business Review*, Vol. 20 No. 1, pp. 33-47.

Papakiriakopoulos, D. and Pramatari, K. (2010), "Collaborative performance measurement in supply chain", *Industrial Management & Data Systems*, Vol. 110 No. 9, pp. 1297-1318.

Phillips, F., Ochs, L. and Schrock, M. (1999), "The product is dead – long live the product service!", *Research-Technology Management*, Vol. 42 No. 4, pp. 51-56.

Ponting, C. (1991), *A Green History of the World*, Sinclair-Stevenson, London.

Prahalad, C.K. and Hamel, G. (2006), "The core competence of the corporation", in Hahn, D. and Taylor, B. (Eds), *Strategische unternehmungsplanung – strategische unternehmungsführung*, Springer, Berlin, pp. 275-292.

Quang, H.T., Sampaio, P., Carvalho, M.S., Fernandes, A.C., An, D.T.B. and Vilhenac, E. (2016), "An extensive structural model of supply chain quality management and firm performance", *International Journal of Quality & Reliability Management*, Vol. 33 No. 4, pp. 444-464.

Rice, J.B. and Caniato, F. (2003), "Building a secure and resilient supply network", *Supply Chain Management Review*, Vol. 7 No. 5, pp. 22-30.

Samvedi, A., Jain, V. and Chan, F.T. (2013), "Quantifying risks in a supply chain through integration of fuzzy AHP and fuzzy TOPSIS", *International Journal of Production Research*, Vol. 51 No. 8, pp. 2433-2442.

Sarkis, J., Shaw, S., Grant, D.B. and Mangan, J. (2010), "Developing environmental supply chain performance measures", *Benchmarking: An International Journal*, Vol. 17 No. 3, pp. 320-339.

Sengupta, K., Heiser, D.R. and Cook, L.S. (2006), "Manufacturing and service supply chain performance: a comparative analysis", *Journal of Supply Chain Management*, Vol. 42 No. 4, pp. 4-15.

Sodhi, M.M.S. and Tang, C.S. (2012), *Managing Supply Chain Risk*, Springer, New York, NY.

Solomon, M., Russell-Bennett, R. and Previte, J. (2012), *Consumer Behaviour*, Pearson Higher Education, AU.

Srinivasan, V. and Kim, Y.H. (1988), "Designing expert financial systems: a case study of corporate credit management", *Financial Management*, Vol. 17 No. 3, pp. 32-44.

Subramaniam, N., McManus, L. and Zhang, J. (2009), "Corporate governance, firm characteristics and risk management committee formation in Australian companies", *Managerial Auditing Journal*, Vol. 24 No. 4, pp. 316-339.

Sweeney, K. (2013), "Health and Safety Executive – annual statistics report for Great Britain 2012/13", available at: www.hse.gov.uk/statistics/overall/hssh1213.pdf (accessed June 7, 2016).

Taticchi, P., Cagnazzo, L., Taticchi, P. and Brun, A. (2010), "The role of performance measurement systems to support quality improvement initiatives at supply chain level", *International Journal of Productivity and Performance Management*, Vol. 59 No. 2, pp. 163-185.

Thun, J.-H. and Hoenig, D. (2011), "An empirical analysis of supply chain risk management in the German automotive industry", *International Journal of Production Economics*, Vol. 131 No. 1, pp. 242-249.

Trkman, P. and McCormack, K. (2009), "Supply chain risk in turbulent environments – a conceptual model for managing supply chain network risk", *International Journal of Production Economics*, Vol. 119 No. 2, pp. 247-258.

Tuncel, G. and Alpan, G. (2010), "Risk assessment and management for supply chain networks: a case study", *Computers in Industry*, Vol. 61 No. 3, pp. 250-259.

Vargo, S.L. and Lusch, R.F. (2004), "Evolving to a new dominant logic for marketing", *Journal of Marketing*, Vol. 68 No. 1, pp. 1-17.

Vargo, S.L. and Lusch, R.F. (2008), "From goods to service (s): divergences and convergences of logics", *Industrial Marketing Management*, Vol. 37 No. 3, pp. 254-259.

Wagner, S.M. and Bode, C. (2008), "An empirical examination of supply chain performance along several dimensions of risk", *Journal of Business Logistics*, Vol. 29 No. 1, pp. 307-325.

Wang, S.-Y., Chang, S.-L. and Wang, R.-C. (2009), "Assessment of supplier performance based on product-development strategy by applying multi-granularity linguistic term sets", *Omega*, Vol. 37 No. 1, pp. 215-226.

Warren, F. (1992), *Introduction in: Royal Society Study Group, Risk Analysis*, Perception and Management, The Royal Society, London.

Williams, T., Eden, C., Ackermann, F. and Tait, A. (1995), "The effects of design changes and delays on project costs", *Journal of the Operational Research Society*, Vol. 46 No. 7, pp. 809-818.

Wu, T., Blackhurst, J. and Chidambaram, V. (2006), "A model for inbound supply risk analysis", *Computers in Industry*, Vol. 57 No. 4, pp. 350-365.

Xie, C., Anumba, C.J., Lee, T.-R., Tummala, R. and Schoenherr, T. (2011), "Assessing and managing risks using the supply chain risk management process (SCRMP)", *Supply Chain Management: An International Journal*, Vol. 16 No. 6, pp. 474-483.

Xu, M., Chen, Y.F. and Xu, X. (2010), "The effect of demand uncertainty in a price-setting newsvendor model", *European Journal of Operational Research*, Vol. 207 No. 2, pp. 946-957.

Yeo, K. and Tiong, R.L. (2000), "Positive management of differences for risk reduction in BOT projects", *International Journal of Project Management*, Vol. 18 No. 4, pp. 257-265.

Zeithaml, V.A., Parasuraman, A. and Berry, L.L. (1985), "Problems and strategies in services marketing", *The Journal of Marketing*, Vol. 49 No. 2, pp. 33-46.

Zsidisin, G.A. and Ellram, L.M. (2003), "An agency theory investigation of supply risk management", *Journal of Supply Chain Management*, Vol. 39 No. 2, pp. 15-27.

Further reading

Alcantara, P. and Riglietti, G. (2015), "Supply chain resilience report 2015", available at: www.riskmethods.net/resources/research/bci-supply-chain-resilience-2015.pdf (accessed July 8, 2017).

Appendix

Table AI. Factor analysis and reliability evaluation

Constructs	Observed items	Factor loadings	Eigenvalue	Variance extracted	Item – total correlation	Cronbach's α
SR	Supplier bankruptcy	0.836	2.612	65.307	0.686	0.822
	Price fluctuations	0.824			0.667	
	Unstable quality of inputs	0.776			0.603	
	Unstable quantity of inputs	0.796			0.628	
OR	Design changes	0.831	2.519	62.964	0.668	0.802
	Technological changes	0.805			0.628	
	Accidents	0.777			0.596	
	Labor disputes	0.759			0.574	
DR	Demand variability	0.742	2.363	59.087	0.539	0.769
	High competition in the market	0.709			0.504	
	Customer bankruptcy	0.803			0.61	
	Customer fragmentation	0.816			0.627	
FR	Currency fluctuations	0.896	2.236	74.52	0.744	0.829
	Inflation	0.838			0.646	
	Interest rate level	0.856			0.673	
	Stakeholders (request late changes, new stakeholders, etc.)			Deleted		
IR	Communication breakdown with project team	0.875	2.274	75.796	0.712	0.837
	Information infrastructure breakdown	0.86			0.686	
	Distorted information	0.876			0.711	
Threshold values		> 0.4	> 1	$> 50\%$	> 0.35	> 0.7

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