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Uncertainty and supply chain risk: The moderating role of supply chain flexibility in risk mitigation

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ABSTRACT

In order to remain competitive in the market, firms are forced to expand their product offerings and offer high levels of customization, bringing about high uncertainty in their supply chain. Firms that face high environmental uncertainty are increasingly facing higher risks in terms of supply disruptions, production and delivery delays that ultimately result in poor operational performance. This study aims at understanding the antecedents of supply chain operational risk faced by firms and the conditions under which such risks can be mitigated. Using Indian data from the sixth edition of International Manufacturing Strategy Survey (IMSS) and structural equation modeling, we investigate the relationships between environmental uncertainty and supply chain risk and the moderating effect of supply chain flexibility. We identify appropriate types of flexibility to mitigate the three major aspects of supply chain risk: supply risk, manufacturing process risk and delivery risk. Our empirical investigation reveals that uncertainty in the supply chain leads to high supply chain risk; and in uncertain environments, supply and manufacturing flexibility help in reducing the supply and manufacturing process risks respectively. However, our results also indicate that, in emerging markets such as India where logistic infrastructure is less developed, internal capabilities alone may not be sufficient in reducing supply chain delivery risk. Our findings not only contribute towards filling certain gaps in the supply chain risk management literature, but also provide practicing managers and researchers a better understanding of the types of flexibility that can mitigate supply chain risk in different business environments.

1. Introduction

"*In retrospect, yes, I sort of wish we had done it after the turn of the year. Customers wouldn't have had to wait as long as they did*" said Tim Cook, the chief executive officer of Apple Inc., in response to the short supply of its redesigned iMac in 2012. "*The new iMac was plagued with production issues when the desktop went on sale in December. It was reported that those issues came from a unique screen lamination process Apple has employed in its new design, allowing the desktop to sport a much thinner profile than its predecessor*".[1] Be it automobiles, mobile phones, computers or any high-end technology products, shorter life cycles necessitate frequent introduction of new products in order to survive in the industry. As a result, companies have to deal with significant uncertainties in the environment (Fisher, 1997; Lee, 2002), which makes the supply chains more complex (Merschmann and Thonemann, 2011). For example, frequent product introductions precipitate demand uncertainty, while wider range of products and higher level of customization in conjunction with advanced technology requirements often create uncertainties in supply as well as production processes (Tang, 2006). Consequently, such firms are increasingly facing higher risks in terms of supply interruptions, production and delivery delays etc. which ultimately result in loss of reputation, lost sales and poor financial performance. A recent survey on global supply chain and risk management shows that repeated changes in product supply and manufacturing requirements because of frequent introduction of new products and less standardization of products and services as key drivers of supply chain complexity leading to increased supply chain risk (Pwc and MIT, 2013). Such risks are attributed to complex supply chains, occur frequently and are referred to as supply chain operational risk (Thun and Hoenig, 2011). In this paper, we study the driving and mitigating factors of supply chain operational risk.

Further, the increasing ramifications of supply chain risks on the performance of firms (Kleindorfer and Saad, 2005) has caught the attention of both academic researchers and industry practitioners in the field of supply chain management (Bogataj and Bogataj, 2007; Matsuo,

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[1] http://forums.appleinsider.com/t/157148/tim-cook-admits-he-wishes-apple-had-held-launch-of-new-imac-until-2013. Last accessed on 06.06.15.

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2015; Li et al., 2015). Supply chain literature is replete with studies that point out how supply chain design could surge or reduce vulnerability of supply chains to risk. For instance, many researchers have argued that supply chain's susceptibility to risk is augmented by supplier dependence (e.g., Hendricks and Singhal, 2005; Jüttner, 2005), supplier concentration and global sourcing (e.g., Tang, 2006; Jüttner, 2005; Tang and Nurmaya Musa, 2011), focus on cost efficient supply chain (Wong et al., 2006) and lack of coordination among the supply chain network partners (Ojala and Hallikas, 2006). However, very few studies have identified mechanisms to tackle these vulnerabilities and mitigate supply chain risk (e.g., Vilko, J. P., & Hallikas, 2012; Wiengarten et al., 2015).

Supply chain flexibility is typically considered as a key solution to the rising uncertainty and competitiveness in the market. Several empirical studies have shown how supply chain flexibility in the presence of uncertain environments has contributed to better business performance (e.g. Martínez Sánchez and Pérez Pérez, 2005; Merschmann and Thonemann, 2011). However, to our knowledge, studies that investigate the role of supply chain flexibility in mitigating supply chain risk empirically, have been very sparse. Tang and Tomlin (2008) for example study the significance of flexibility in mitigating supply chain risks using analytical modeling. Furthermore, while many practitioner surveys and industry based studies identify that flexibility is key to managing supply chain risk; it is not clear exactly how much and what type of flexibility is required to mitigate supply chain risks (Tang and Tomlin, 2008). Pujawan (2004) points out that firms should be prudent in evaluating the right amount of flexibility they require, since it is expensive to achieve high levels of flexibility. For instance, a 2013 survey on supply chain innovation shows that only 27% of the respondents considered flexibility as one of the top two key supply chain value drivers for their customer value proposition (Pwc and MIT, 2013). Therefore, it is imperative to understand and identify the contexts under which various types of flexibility would help reduce supply chain risk and test these conjectures through appropriate empirical investigations.

There have been many calls for more empirical research in the field of operations and supply chain management in the last decade, as this helps in theory building and verification (Flynn et al., 1990; Fisher, 1997), and strengthens the link between academics and practitioners in operations management (Steenhuis and Bruijn, 2006). While several case based studies (eg., Hallikas et al., 2004; Tang, 2006) and conceptual studies (e.g., Trkman and McCormack, 2009; Tang and Nurmaya Musa, 2011) have been carried out in the area of supply chain risk identification and mitigation, empirical survey based research is still at a nascent stage. Thun and Hoenig (2011) and Sodhi et al. (2012) also point out the dearth of empirical investigation in the field of supply chain risk management. Therefore, there is a clear need for empirically establishing the linkages between various elements discussed above, such as supply chain flexibility, environmental uncertainty and supply chain risk in order to fill the gaps in operations and supply chain management empirical research.

The objective of this study therefore is to address these research gaps and to identify appropriate types of flexibility that can help mitigate supply chain risk. We study three major aspects of supply chain risk: supply risk, manufacturing process risk and delivery risk. Using data from 91 Indian manufacturing firms, and structural equation modeling, we investigate the relationships between environmental uncertainty and supply chain risk, and the moderating effects of supply chain flexibility. Emerging economies play a significant role in global trade and account for 50% of global output.[2] While they present enormous growth prospects, they also pose unique challenges primarily due to low maturity of supply chain processes.[3] Given the critical role that emerging markets such as China and India are playing in global supply chains, it is important to study the driving and moderating factors of supply chain risk in these geographical regions. We strongly believe that our findings not only contribute towards filling certain gaps in the SCRM literature, but also help practicing managers and researchers by providing a better understanding of the types of supply chain flexibility that can mitigate supply chain risk in different business environments.

2. Theoretical constructs and hypotheses development

Several different sources of uncertainty have been recognized in Supply Chain Management (SCM) literature (Ho et al., 2005; Trkman and McCormack, 2009) that create an uncertain business environment for firms. Davis (1993) for example proposes three main sources of supply chain uncertainty: demand, supply and technology. In our study, we consider a fourth dimension ‘manufacturing uncertainty’ (Ho et al., 2005), in addition to the three proposed by Davis (1993), to operationalize the environmental uncertainty construct.

Many different theoretical perspectives have contributed to the understanding of supply chain risk. Kumar et al. (2010) for example define supply chain risk as “*the potential deviations from the initial overall objective that, consequently, trigger the decrease of value-added activities at different levels*” (p 3717). Supply chain risk can also be broadly categorized into *disruption risk* and *operational risk* (Kleindorfer and Saad, 2005; Tang, 2006). While *disruption risks* are linked to circumstances such as natural calamities, terrorist attacks and labor strikes, *operational risks* are caused by high uncertainty and a lack of coordination between supply and demand (Lockamy and McCormack, 2010). *Operational risk* is also alluded to as internal supply chain risk (Thun and Hoenig, 2011). According to an industry study by Deloitte, the supply chain risks of “*high tech industrial products, and diversified manufacturing industries*” had become more costly owing to the complex nature of their supply chains and rapidly changing market needs leading to sudden changes in demand. Forty six percent of executives surveyed pointed out risks within the company-owned supply chain operations as a major concern (Marchese and Paramasivam, 2013). In the context of this study, we only focus on *operational risk* in supply chains. A conceptual framework representing how environmental uncertainty, and the various dimensions of supply chain flexibility and supply chain risk are related is shown in Fig. 1. The relationships between these constructs as depicted in the framework are discussed in more detail followed by corresponding hypotheses, in the subsections below.

2.1. *Environmental uncertainty and supply chain risk*

Firms that have a product line characterized by frequent introduction of new offerings, wider variety and higher level of customization find it difficult to predict the demand patterns of the products (Fisher, 1997; Lee, 2002; Lo and Power, 2010). While demand uncertainty, which primarily involves the unknowns related to product characteristics, is one of the major sources of uncertainty in the supply chain, there are other sources of uncertainty as well, including manufacturing and supply uncertainty (Ho et al., 2005). While innovative and highly customized product offerings help firms gain a sustainable competitive advantage (Calantone et al., 2010), these also result in higher complexity in the manufacturing and procurement processes of upstream suppliers, leading to higher uncertainty in the entire supply chain (eg., Randall and Ulrich, 2001). Frequent changes in production technology not only increase complexity of manufacturing, but also forces technical modifications at the suppliers end as well. In addition, the greater changes in order size result in frequent changes not only in the firm's production but also in their supplier's production volume and mix. Supply uncertainty is therefore characterized by unforeseeable and unmanageable factors in the supply of materials mainly attributed to technological complexity (Davis, 1993), and manufacturing variability in product mix and volume.

Supply risk on the other hand is defined as the probable failure in the supply of goods in terms of “*time, quality and quantity*” resulting in incomplete orders (Kumar et al., 2010). The unpredictable market

[2] http://www.fin24.com/Economy/Focus-on-emerging-markets-20130726. Last accessed on 26.06.15.

[3] http://www.bvdinfo.com/industrynews/procurement-and-risk-management/supply-chains-key-to-emerging-market-growth/801614149. Last accessed on 26.06.15.

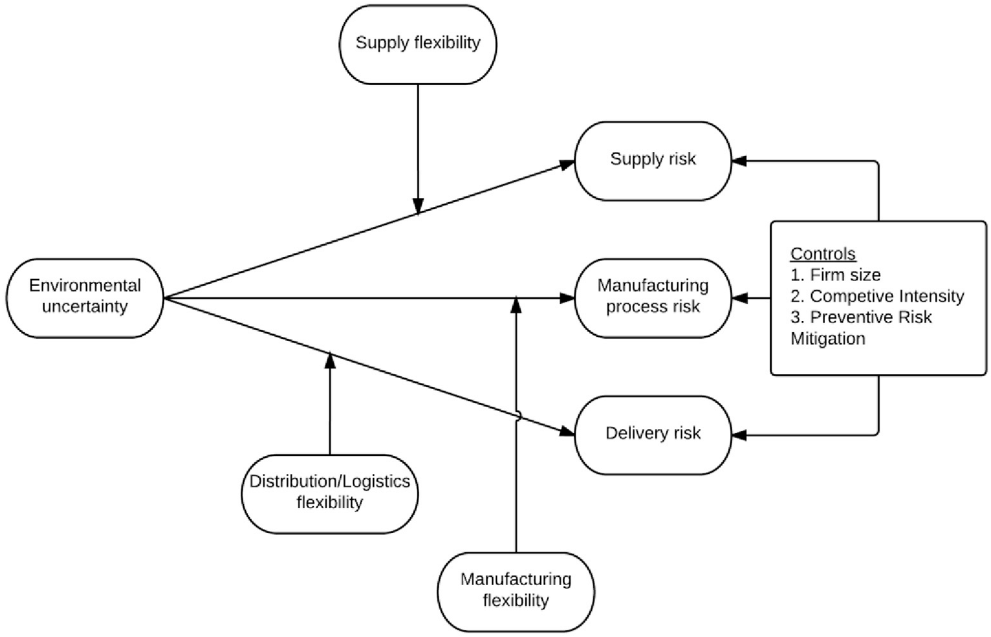

Fig. 1. Conceptual framework.

response to innovations increases the risk of shortfall or excess of supplies (Fisher, 1997). Further, owing to rapid swings in demand and supply characteristics of the products, the possibility of losses due to delivery of wrong products or delivery of right products, but at the wrong time is very high (Forza and Salvador, 2002). In addition, as the uncertainty in volume or mix requirements of an order increases, suppliers' ability to deliver on time and in right quality reduces (Thun and Hoenig, 2011). Based on the above arguments, we posit the following hypothesis:

H1a. Firms that have high environmental uncertainty are exposed to high supply risk.

Manufacturing process risk may be defined as the '*probable deviances from making the desired quality and quantity at the right time*' (Kumar et al., 2010). Uncertainty due to shorter product life cycle or frequent introduction of new products leads to greater variability in the manufacturing systems (Ho et al., 2005; Manuj and Mentzer, 2008). The unforeseen changes in the supply or order fluctuations from customer induce variations into the production processes (Chen et al., 2013). When a firm is expected to provide greater flexibility in order size and degree of customization, and deliver them at a faster speed, it becomes very difficult for the firm to maintain a stable production environment on the shop floor. For example, greater variations in order size call for order insertion, expedition or changes in volume and mix, resulting in unpredictability in the throughput time, process yield and product quality. This subsequently results in unstable and unreliable performance of the production processes and triggers manufacturing process risk (Chen et al., 2013). Therefore, we hypothesize the following:

H1b. Firms that have high environmental uncertainty are exposed to high manufacturing process risk.

Maintaining high levels of inventory at customer's site as well as their own warehouses is one of the key strategies followed by firms to meet the delivery reliability norms (Lutz et al., 2003). However, the high frequency product changes and new product introductions, coupled with greater variety and customization would make it very difficult to maintain adequate levels of finished goods inventories. In addition, the uncertainty in market demand associated with innovative products with shorter lifecycles affect the accuracy levels of demand forecasts and associated inventory levels. The uncertainty in demand, manufacturing and supply environments therefore has a potential to affect delivery quality and reliability both in terms of delivering the right product as well as at the right time. Thus, we conjecture that firms operating in highly uncertain environments are more vulnerable to delivery failures, and posit the following hypothesis:

H1c. Firms that have high environmental uncertainty are exposed to high delivery risk.

2.2. *The moderating role of supply chain flexibility on supply chain risk*

So, how can firms that face uncertain environment, resolve the challenges posed by supply chain risk? Studies have found that timely mitigation of adverse effects of uncertainty is crucial for effective functioning of a supply chain (Naylor et al., 1999; Merschmann and Thonemann, 2011). Some researchers have emphasized that, firms should consider investing in supply chain agility and responsiveness (e.g., Chopra and Sodhi, 2004; Oke and Gopalakrishnan, 2009; Braunscheidel and Suresh, 2009) in order to respond speedily to marketplace fluctuations and to manage disruption risk. However, according to Fisher (1997) and Lee (2002), a firm's choice of supply chain strategy should be based on the genre of product it offers – functional or innovative and its demand characteristics. Several authors have tested Fisher's (1997) model and corroborated the need for alignment between product characteristics and supply chain design for firm performance (e.g. Qi et al., 2009 and Wagner et al., 2012). Gonzalez-Benito (2007) also points out the importance of matching supply capabilities with a firm's operating environment in order to keep pace with changing business requirements.

As mentioned earlier, supply chain flexibility has been recognized as one of the key levers to reduce supply chain risk in many conceptual as well as industry based studies. Flexibility is defined as "*the ability to change or react with little penalty in time, effort, cost or performance*" (Upton, 1994, p.73). Our conceptualization of supply chain flexibility incorporates three dimensions of flexibility – (i) supply flexibility, (ii) manufacturing flexibility, and (iii) distribution/logistics flexibility, drawn from different sources in the literature. Supply flexibility essentially captures how flexible a firm's upstream supplier network is and is characterized by flexible supply base, flexible supply contracts and collaborative supplier relationships (Swafford et al., 2006; Liao et al., 2010). Manufacturing flexibility, one of the most vital components of supply chain flexibility (Vickery et al., 1999), is the capability of the firm to control production resources and manage uncertainty to fulfill customer needs (Zhang et al., 2003). Adapting from the definition given by Hall (1983) and Pagell and Krause (2004), we operationalize manufacturing flexibility in terms of mix flexibility, volume flexibility, and product modification flexibility. For distribution/logistics flexibility, we adopt the definition given by Swafford et al. (2006, p.176) that defines this capability as "*the availability of a range of options and the ability to effectively exploit them so as to adapt the process of controlling the flow and storage of materials, finished goods, services, and related information from origin to destination in response to changing marketplace conditions*".

Supply chain flexibility in general is considered as a competitive response to environmental uncertainty (Merschmann and Thonemann, 2011) and to optimize the flow of goods through the complex networks of supply chains (Garavelli, 2003). Therefore, one would expect that, supply chain flexibility should also aid firms in mitigating supply chain risk arising from environmental uncertainty. Several studies have shown that a match between the environment and the organizational structure is crucial for firm performance (Hillsdale Covin and Slevin, 1989; Wu et al., 2014; Wong et al., 2015) and in particular studies have reiterated the need for a fit between uncertainty and supply chain flexibility for operational and firm performance (e.g., Fisher, 1997; Merschmann and Thonemann, 2011). We posit that firms that align their environmental uncertainty with supply chain flexibility will be able to mitigate supply chain risk better than firms that do not align.

Since we have divided Supply chain risk into three separate components (supply risk, manufacturing risk and delivery risk), we identify the corresponding flexibility strategies (supply flexibility, manufacturing flexibility and distribution/logistics flexibility) that aid in mitigation of respective component of supply chain risk.

It is evident from the extant supply chain literature that increased competition in the market place and increasing uncertainty in the supply chain primarily drive firms to build flexible supply contracts and have a collaborative relationship with their suppliers (Modi and Mabert, 2007; Li et al., 2012). Effective supplier relationship is a key element of supply flexibility (Prajogo et al., 2012) that not only increases a firm's responsiveness to changing material requirements in uncertain environments (Day et al., 2015) but also increases willingness of suppliers to share the risks (Cooper and Ellram, 1993; Hallikas et al., 2004). Further, several studies have shown that supplier involvement in new product development and design modifications help reduce the supply failures arising from product lead-time issues in uncertain times (e.g., Ragatz et al., 2002; He et al., 2014). Supply flexibility in the form of a flexible supply base also aids in reducing the risk of supply shortages when a key supplier fails to supply due to high product uncertainty (Lee, 2002).

In order to produce assorted products competently, a firm is expected to improve process flexibility by adopting flexible manufacturing systems (Sethi and Sethi, 1990). Several studies have emphasized the need for several dimensions of manufacturing flexibility in the face of environmental uncertainty to effectively reduce the adverse impact of uncertainty on performance (e.g., Chang et al., 2003; Lloréns et al., 2005; Francas et al., 2011). While mix flexibility decreases uncertainty with respect to meeting customer preference in terms of product performance and features, volume flexibility mitigates uncertainty in quantity to be delivered by enabling the firm to produce exact amount of product required by the customer (Zhang et al., 2003).

Similarly, firms having distribution and logistics flexibility exhibit greater levels of agility within the supply chain in terms of delaying commitment and modifying delivery schedules in order to meet unpredictable and changing customer requirements (Zhang et al., 2005; Swafford et al., 2006). Further, as the last link to the customer, distribution flexibility is crucial for greater adaptability and responsiveness to uncertain market demands (Van Hoek, 2001) and hence helps in reducing the risk of delivery failures.

Based on the above arguments, we posit the following hypotheses:

H2a. Supply flexibility moderates the relationship between environmental uncertainty and supply risk.

H2b. Manufacturing flexibility moderates the relationship between environmental uncertainty and manufacturing risk.

H2c. Distribution/logistics flexibility moderates the relationship between environmental uncertainty and delivery risk.

3. Research methods

3.1. Sampling and data collection

We validate the model shown in Fig. 1 using Indian data from International Manufacturing Strategy Survey (IMSS). The IMSS was developed by a global network of academic researchers to measure the *strategies, practices, and performance* of manufacturing firms across the globe. IMSS is being carried out since 1992 and updated every four years. It includes survey of manufacturing firms that belong to the ISIC codes from 25 to 30. Some of the studies that were published using data collected through previous IMSS rounds include operations strategy studies such as Frohlich and Westbrook (2001); Yang et al. (2011); Roh et al. (2014); Golini and Kalchschmidt (2015).

We use data from the sixth edition of the IMSS, which was conducted in 2013. Overall, 22 countries participated in this edition and a total of 932 survey responses were obtained. In the current study, we use the data from 91 Indian manufacturing firms that we collected as part of IMSS 2013 survey. The survey was filled by senior managers and executives, of a level equivalent or higher than the production manager of the plant. The unit of analysis in this study is the plant and not the business unit or the company. Participating plants had to have a minimum of 50 employees, to become eligible to participate in the survey. The interviewees personally met all respondents within a firm to administer the survey. Each section of the survey was filled in by the respective functional heads, and it took the respondents almost 4 h to fill in each survey. The interviewees provided clarifications wherever necessary and the respondents were assured of anonymity and confidentiality of information provided. Table 1 provides the overview of our sample.

3.2. Measures

The constructs used in this study were measured using multiple items from the survey. The items used to measure each construct are based on the existing literature. The *environmental uncertainty* construct is measured in terms of demand, manufacturing, supply and product

Table 1
Profile of firms that participated in the IMSS survey.

Metric	Number	Percentage
Industry grouping		
Fabricated metal products (ISIC 25)	11	12
Computer, electronics and optical products (ISIC 26)	27	30
Electrical Equipment (ISIC 27)	18	20
Machinery and equipment not elsewhere classified (ISIC 28)	15	16
Motor vehicles, trailers and semi-trailers (ISIC 29)	13	14
Other transport equipment (ISIC 30)	7	8
Sales Volume		
<10 million €	16	18
10-50 million €	40	44
51-100 million €	19	21
101-500 million €	14	15
>500 million €	–	–
N.a.	2	2
Number of employees		
<500	54	59
500–1000	24	26
1001–2500	8	9
>2500	5	5
N.a.	–	–

uncertainties based on prior research (e.g., Chen and Paulraj, 2004; Ho et al., 2005; Merschmann and Thonemann, 2011). Demand uncertainty includes measures that represent fluctuations in demand, whereas manufacturing uncertainty captures production variations in volume and mix requirements of the products. Supply uncertainty consists of indicators that represent fluctuations in supply requirements and variations due to frequent modifications to the parts and components supplied. Product uncertainty is measured in terms of the technical complexity of the products and the degree of technological changes apparent within the industry.

As proposed by Thun and Hoenig (2011), we measure *Supply chain risk* construct in terms of the probability of occurrence of an event and the corresponding impact of that event with reference to supply failure, manufacturing operations failure and delivery failure. For *flexibility* construct, we consider three dimensions of flexibility – flexibility in supply, manufacturing and logistics (Swafford et al., 2006). Supply flexibility is measured in terms of the availability of a flexible supply base with a range of options, involvement of the key supplier in new product development and design modifications and having flexible supply contracts (Ragatz et al., 2002; Chen and Paulraj, 2004; Swafford et al., 2006). While several scales are available in the literature that measure manufacturing flexibility, we measure this construct using items such as having excess capacity, excess labor and product postponement (Bengtsson and Olhager, 2002; Brun and Zorzini, 2009). Maintaining excess capacity and excess labor helps in achieving a product mix flexibility in terms of both quick changeovers between products and volume changes within a given product mix (Bengtsson and Olhager, 2002) and having a product postponement capability helps in achieving flexibility in product customization (Brun and Zorzini, 2009). Distribution and logistics flexibility include indicators that represent availability of flexible modes of transportation and having an international distribution strategy for controlling the movement and warehousing of goods (Swafford et al., 2006).

In addition, we use three control variables which may influence the main variables in our model and cause unwanted sources of variance. First, we account for firm size which may impact the adoption of supply chain risk management practices (e.g., Zhu et al., 2008 and Kim, 2009) and use number of employees in the plant as a measure of size. Second, we control for competitive intensity which is the degree to which a firm perceives the intensity of its competition in the market (Wagner et al., 2012) and could have impact on supply chain risk (Xiao and Yang, 2008; Trkman and McCrmack, 2009). The competitive intensity construct is measured through items such as market concentration, competitive rivalry within the industry, and market entry (Ramaswamy, 2001). Third, we control for preventive risk mitigation which may impact supply chain risk. Table 2 shows the summary of the items used to measure each construct.

Table 2
Measures used in proposed constructs.

Dimension	Item	Item Description
Environmental uncertainty (EU)	EU1	Demand fluctuates drastically from week to week
	EU2	Total manufacturing volume fluctuates drastically from week to week
	EU3	Mix of products you produce changes drastically from week to week
	EU4	Supply requirements (volume and mix) vary drastically from week to week
	EU5	Products are characterized by a lot of technical modifications
	EU6	Suppliers frequently need to carry out modifications to the parts/components they deliver to your plant
Supply flexibility (SF)	SF1	Maintaining a flexible supply base
	SF2	Developing collaborative approaches with key suppliers
	SF3	Joint decision making with key suppliers (about product design/modifications, process design/modifications, etc.)
Manufacturing flexibility (MF)	MF1	Maintaining excess capacity
	MF2	Maintaining excess labour
	MF3	Product postponement
Distribution/ logistics flexibility (DF)	DF3	Flexible modes of transportation (multi-modal, multi-carrier, multi-route transportation)
	DF4	Developing an international distribution strategy
Supply risk (SR)	SR1	A key supplier fails to supply affecting your operations - probability
	SR2	A key supplier fails to supply affecting your operations - impact
Manufacturing process risk (MR)	MR1	Your manufacturing operations are interrupted affecting your shipments - probability
	MR2	Your manufacturing operations are interrupted affecting your shipments - impact
Delivery risk (DR)	DR1	Your shipment operations are interrupted affecting your deliveries - probability
	DR2	Your shipment operations are interrupted affecting your deliveries - impact
Competitive intensity (CI)	CI1	Market concentration
	CI2	Competitive rivalry within industry
	CI3	Market entry
Preventive risk mitigation (PRM)	PRM1	Preventing operations risks (e.g. select a more reliable supplier)
	PRM2	Detecting operations risks (e.g. internal or supplier monitoring)
Firm size (FS)	FS1	Number of employees

3.3. Data analysis approach

We adopt structural equation modeling (SEM) using the partial least square (PLS) method to test the conjectures proposed in this study. PLS is one of the most widely used methods for investigating the direct and indirect effects of numerous variables simultaneously (Hair et al., 2011). The PLS-SEM approach is a non-parametric method and does not require multivariate normality of data (Chin, 1998) and its application is aimed to maximize the explained variance of the endogenous latent constructs and minimize the unexplained variances (Leguina, 2015). Also, since PLS is built on a series of OLS regressions, it doesn't pose restrictions on sample size unlike the covariance based SEM and usually provides higher statistical power (Chin, 1998; Reinartz et al., 2009). This technique is primarily used when the research objective is theory development and explanation of variance. As the research field of our study is less mature and exploratory in nature (Sodhi et al., 2012), PLS-SEM is a preferred technique (Grötsch et al., 2013).

We use SmartPLS, Version 2.0 M3 for the analysis (Ringle et al., 2005). We test the significance of path coefficients and item loadings using a bootstrapping technique involving 1000 repetitions (Nevitt and Hancock, 2001).

4. Results

4.1. Measurement model assessment

To determine the reliability and validity of the constructs, we carried out confirmatory factor analysis (CFA) and used four tests to assess the convergent validity and the internal consistency of the reflective constructs: item loading, Cronbach's alpha, composite reliability (CR) and average variance extracted (AVE) of the constructs (Fornell and Larcker, 1981; Straub et al., 2004). Table 3 presents the survey items, psychometric properties and descriptive statistics for each of the constructs. All item loadings, Cronbach's alpha (α) and CR values surpass the 0.7 cut off recognized in the literature. Also, all scales exceeded the accepted 0.50 cut-off for AVE. The results confirm that the convergent validity of all the constructs used in our models is satisfactory (Fornell and Larcker, 1981).

To examine discriminant validity, the AVE and CR were compared with the squared correlations of the latent constructs, as shown in Table 4. The AVE and CR values were larger than the squared inter-construct correlation values shown in the off-diagonal of the

Table 3
Measurement model results (descriptive statistics, factor loadings, item reliability and convergent validity).

Factor	Item	Mean	SD	Loading/ Weight	*t*-value
Environmental uncertainty ($\alpha = 0.91$, CR = 0.92, AVE = 0.68)	EU1	0.78	0.05	0.78	15.17
	EU2	0.82	0.04	0.82	21.24
	EU3	0.73	0.05	0.77	13.88
	EU4	0.84	0.04	0.85	20.55
	EU5	0.85	0.02	0.81	35.97
	EU6	0.90	0.02	0.87	49.55
Supply flexibility ($\alpha = 0.75$,CR = 0.83, AVE = 0.63)	SF1	0.62	0.40	0.81	2.02
	SF2	0.66	0.41	0.94	2.26
	SF3	0.58	0.39	0.60	1.56
Manufacturing Flexibility ($\alpha = 0.84$, CR = 0.89, AVE = 0.68)	MF1	0.83	0.03	0.84	25.86
	MF2	0.71	0.05	0.71	13.88
	MF3	0.88	0.02	0.88	44.98
	MF4	0.86	0.03	0.86	33.84
Delivery flexibility ($\alpha = 0.75$, CR = 0.84, AVE = 0.56)	DF1	0.67	0.10	0.78	7.20
	DF2	0.62	0.11	0.76	5.79
	DF3	0.81	0.05	0.70	16.45
	DF4	0.85	0.04	0.74	20.53
Supply Risk ($\alpha = 0.62$, CR = 0.80, AVE = 0.68)	SR1	0.97	0.03	0.98	39.05
	SR2	0.62	0.16	0.63	4.00
Manufacturing Risk ($\alpha = 0.72$, CR = 0.86, AVE = 0.76)	MR1	0.96	0.02	0.96	61.89
	MR2	0.77	0.07	0.77	10.54
Delivery Risk ($\alpha = 0.77$, CR = 0.89, AVE = 0.81)	DR1	0.93	0.01	0.94	66.04
	DR2	0.86	0.04	0.87	24.74
Competitive Intensity ($\alpha = 0.58$, CR = 0.75, AVE = 0.52)	CI1	0.60	0.21	0.67	3.24
	CI2	0.47	0.26	0.54	2.10
	CI3	0.84	0.21	0.90	4.35
Preventive Risk Mitigation ($\alpha = 0.76$, CR = 0.85, AVE = 0.62)	PRM1	0.71	0.25	0.69	7.55
	PRM2	0.62	0.32	0.61	6.84
Firm Size	FS1	0.48	0.87	1.00	–

correlation matrix, thereby confirming a satisfactory level of discriminant validity (Fornell and Larcker, 1981).

4.2. Common method bias assessment

A major problem with survey-based study is the presence of common method variance (CMV). To avoid this, firstly, our survey was conducted with multiple respondents. Each survey was answered by senior executives ranging from general manager to managers of production, purchasing, marketing and supply chain functions. We next evaluated CMV by means of Harmon's one-factor assessment (Podsakoff and Organ, 1986), as a secondary measure to ensure there is no bias. As mentioned earlier, we did exploratory factor analysis with principal components extraction and no rotation for all the constructs. The presence of common method bias would have caused a single factor contributing to a major percentage of covariance in the variables. Our result shows that no single factor stands out in the factor structure and eight factors had Eigen values more than the cut-off value of one, with the first factor explaining for 20.53% of the variance. Also, through a confirmatory analysis, we corroborated this finding (Byrne and Stewart, 2006). Therefore we can safely assume that, common method bias is not a threat in this study.

4.3. Structural model assessment

Our PLS structural model was evaluated for the significance of the hypothesized path coefficients and its explanatory power. As the number of missing values exceeded 5 percent, we used a case-wise deletion method as suggested in the literature (Tsikriktsis, 2005). As a result of this, our sample size reduced to 84 from 91. Further, we checked for potential collinearity issues in the model. We followed the method suggested by Wong (2013) and used the latent variable scores from PLS calculation results as input for multiple regression in SPSS and determined the Variance Inflation Factor (VIF). We found that VIF was much less than 5 which is a rule of thumb to evade collinearity problem (Hair et al., 2011). Fig. 2 shows the results of the structural model along with standardized path coefficients, the corresponding levels of significance and the amount of variance explained (R^2) by the model.

As discussed in Section 3, this empirical study investigates the relationship between environmental uncertainty and supply chain risk and the moderating effect of supply chain flexibility on the relationship between environmental uncertainty and supply chain risk. Our hypothesised model explains 31.2%, 76.3% and 73.1% of the variances (R^2) in SR, MR and DR respectively, confirming sufficient predictive power (Chin, 1998). Further, we determined the Stone-Geisser's Q^2 values through the blindfolding method (Henseler et al., 2009). The Q^2 values are 0.28, 0.35 and 0.29 for SR, MR and DR respectively and these positive values confirm that our structural model has satisfactory predictive power (Henseler et al., 2009).

4.3.1. Moderation analysis

In order to test Hypotheses H2a, H2b and H2c, we considered the effects of the three dimensions of supply chain flexibility on the relationship between environmental uncertainty and the supply chain risk elements. The moderating effect can be analyzed by looking at the impact of interaction terms formed by the cross product of environmental uncertainty construct and the three dimensions of supply chain flexibility constructs, on the corresponding supply chain risk elements (Chin et al., 2003). As proposed by Baron and Kenny (1986), the moderator hypotheses are supported when the path coefficients between the interaction term and the dependent variable are significant. Analysis of the results as shown in Fig. 2 reveals that the moderating effects of supply and manufacturing flexibility are significant on supply risk (interaction effect $\beta = -0.31$, p-value <0.05) and manufacturing process risk (interaction effect $\beta = -0.18$, p-value < 0.1) respectively, providing support for Hypotheses H2a and H2b. However, the moderating effect of distribution/logistics flexibility on delivery risk is not significant (interaction effect $\beta = 0.06$, p-value >0.1) and hence hypothesis H2c is not supported.

We evaluated the strength of the moderating effects using the effect size (Cohen, 1988). Accordingly, we compared the amount of the variance explained (R^2) of the base model with the R^2 of the full model, which includes the three moderating effects. The f^2 effect size value for supply risk is 0.18, for manufacturing process risk is 0.19 and for delivery risk is 0.16. An effect size value above 0.15 indicates a medium effect (Cohen, 1988), thereby showing evidence for moderating effects of

Table 4
AVE and squared correlations for discriminant validity assessment.

Construct	CR	EU	SF	MF	DF	SR	MR	DR	PRM 0.52	CI
EU	0.92	**0.68**								
SF	0.83	0.16	**0.63**							
MF	0.89	0.15	0.07	**0.68**						
DF	0.84	0.18	0.29	0.36	**0.56**					
SR	0.80	0.21	0.01	0.16	0.20	**0.68**				
MR	0.86	0.12	0.03	0.22	0.27	0.59	**0.76**			
DR	0.89	0.26	0.02	0.15	0.19	0.61	0.65	**0.81**		
PRM	0.85	0.15	0.23	0.12	0.19	0.11	0.13	0.08	**0.62**	
CI	0.75	0.06	0.05	0.01	0.04	0.06	0.05	0.07	0.03	**0.52**

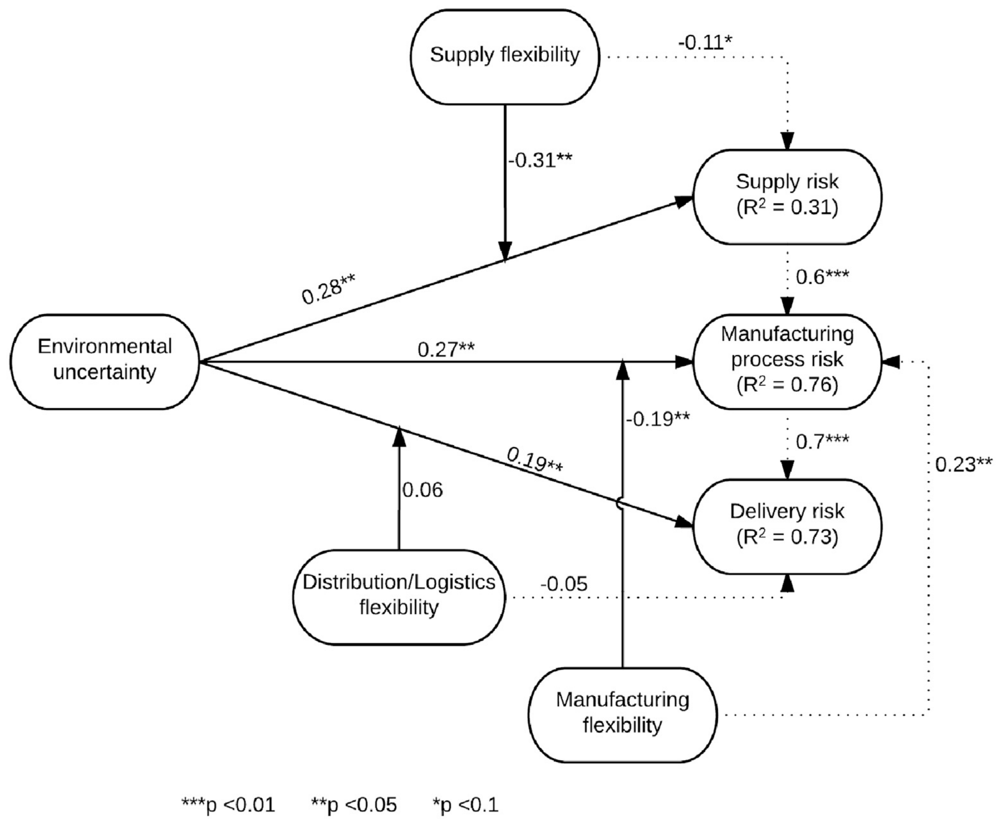

Fig. 2. Path model.

supply and manufacturing flexibility. The results suggest that in uncertain environments, supply and manufacturing flexibility helps in mitigating supply and manufacturing risk respectively, while having distribution and logistics flexibility doesn't necessarily lead to reduction in delivery risk.

5. Discussion, managerial implications and conclusions

This study empirically analyzes the connection between a firm's uncertainty in its operating environment and its vulnerability to supply chain risk and the conditions under which such risks could be mitigated. To our knowledge, there have been very few studies in supply chain risk management literature that focus on the empirical investigation of drivers of supply chain risk and the role of risk mitigation strategies in reducing the risk. This study not only establishes the linkages between environmental uncertainty and supply chain risk, but also provides empirical validations of the benefits of supply, manufacturing and distribution/logistics flexibility in reducing respective supply chain risks.

In order to remain competitive in the market, firms are forced to expand their product offerings and offer high levels of customization, bringing about high uncertainty in their supply chain. Failure to develop the requisite capabilities to tackle these uncertainties can create ripple effects in the firm's supply chain, which in turn could result in a greater probability of supply failure as well as failure to deliver the right products at the precise time to the customer. Due to the high interconnectedness of the supply chain, failure of one firm not only affects its own performance but also impacts firms in both upstream and downstream of the supply chain, making them more vulnerable to risks. While high uncertainty in the supply chain may be inevitable in today's highly competitive environment, this uncertainty need not necessarily lead to higher risks, if firms have put in place flexible supply and manufacturing systems as counter measures.

While several industry practitioners underscore the importance of having flexible supply chain processes to cater to changing market requirements, many fail to invest in establishing a flexible supply chain. Two main reasons for this could be that flexibility is costly and it is difficult to see the immediate benefits of having such a capability. Further, it is crucial to choose the right kind and level of flexibility that fits the environment in which the firm is operating. For instance, our results show that firms that have high uncertainty are more vulnerable to risks in the supply chain; however, having the appropriate supply chain flexibility measures in place mitigates those risks. Our findings suggest that the dimensions of supply chain flexibility, in themselves, are not much helpful in mitigating supply chain risk. We argue that their effect is context-dependent and our results support the contention that firms must align their flexibility capabilities with the environment in which they are operating. Specifically, we find that supply and manufacturing flexibility moderate the relationship between environmental uncertainty and the corresponding supply chain risk elements and hence demonstrate uncertain environment as a key context for the effectiveness of supply chain flexibility in mitigating supply chain risk. Therefore, firms that match their supply and manufacturing flexibility with uncertainty have lower supply and process risk respectively than firms that haven't established this match. When firms face less uncertainty in their operating environment, they can bank on their existing resource base with less dependence on flexibility. Our findings corroborate the theoretical claims of Fisher (1997) and Lee (2002) that innovative products (characterized by high uncertainty) require flexible supply chains, whereas functional products (characterized by low uncertainty) require efficient supply chains. Therefore, our empirical results clearly point to the need for alignment between the level of flexibility to be developed depending on the level of uncertainty a firm is exposed to.

For example, one of the interesting results from our study, although not part of the main results is that the direct effect of manufacturing flexibility on manufacturing process risk is positive and significant. This essentially implies that high manufacturing flexibility, in the context of low or no environmental uncertainty in fact increases manufacturing risk. This result is in line with Kulatilaka and Marks (1988) who point out that "*the strategic value of flexibility can, under some conditions, be negative*", primarily in environments with very low uncertainty. To elaborate, in an environment characterized by stable demand, lower product variants and longer product life cycles, a general-purpose machine with high mix and volume flexibility would not be of much help in fulfilling the customer orders and in fact turn out to be very inefficient. High volume-low variety production environment requires special purpose machines with high automation to achieve competitiveness in the market (Hill and Chambers, 1991; Beach et al., 2000). Hence in the absence of uncertain environments, manufacturing flexibility which is externally driven leads to higher process risk. This is also in line with the findings of numerous studies that have shown the multi-dimensional nature of manufacturing flexibility (e.g., Gerwin, 1987; Koste et al., 2004) and the need for carefully choosing the right type and level of flexibility contingent on the operating environment of the firm (Cai and Yang, 2014).

Another interesting finding of our study, as one may note from Fig. 2, is that supply risk can cause manufacturing risk which in turn can cause delivery risk. This implies that there is a cascading effect of supply side risk on a firm's downstream supply chain and hence a firm's focus on mitigating supply risk would also benefit the firm in mitigating its manufacturing and delivery risks.

While we also expected distribution/logistics flexibility to have a moderating impact on delivery risk; we did not find a significant relationship. One possible explanation for this could be that delivery flexibility measures adopted by the firms are largely internal to the firm. However, delivery/shipment risk is in general attributed not only to the internal process and distribution flexibility related aspects of the firm but also to the poor logistics infrastructure that is external to the firm. For instance, a 2012 survey of global trade logistics by the World Bank reveals that firms that are located in countries that rank low on their logistics performance index are likely to suffer due to lack of proper infrastructural support (Arvis et al., 2012). This is relevant in the present context of our study which is based on the Indian manufacturing firms. In comparison with the global trade logistics networks, the Indian logistics network ranks very low on the quality of its logistics infrastructure and a recent study (Deloitte report, 2014) also reveals the inadequacy of the transportation infrastructure in India. In addition, various customs duties and other related bureaucracy for transportation of goods between various states in India also adds to the delays, exposing the firms to delivery risks. Therefore, even if a firm has multiple modes of transport as backup option, these external factors may hinder on-time delivery, making distribution/logistics flexibility ineffective. Hence, the firm's distribution/logistics flexibility measures perhaps are not sufficient in explaining the delivery risk; and the logistics capabilities of the country in which the firm is operating in, also are likely to play a crucial role in reducing this risk.

Overall, our results strongly indicate that having the right type of supply chain flexibility is a key risk mitigation tool for firms operating in highly uncertain environments.

5.1. Managerial implications

The findings from this study should help managers in three important ways. Firstly, they show that the benefit of flexibility is contingent upon several factors, including the dimension of supply chain risk the firm is exposed to and the type of the environment in which the firm is functioning. Especially since we find evidence that only a fit between flexibility and uncertainty helps in mitigating the risks, it is all the more critical for managers to justify and carefully develop the appropriate level of flexibility depending on the firm's strategic objectives that drive its environment and the nature of risk it is exposed to, in order to realize the full benefits of flexibility. Secondly, our results provide a clear picture of the role of different types of flexibility in mitigating different types of risks, therefore empirically establishing a one-to-one correspondence between the types of flexibility and the types of risks. Thirdly, given that building supply chain flexibility capabilities is a costly affair, our results aid in understanding that not all flexibility strategies on their own can mitigate supply chain risk. For example, managers need to consider the possibility that delivery/logistics flexibility may not be sufficient in mitigating their firm's delivery risk. Our study findings therefore indicate that firms in global supply chains cannot always depend on their internal capabilities alone to mitigate their supply chain operational risk, but also need to work with local institutions to develop better infrastructural capabilities, which will benefit everyone in the long run.

5.2. Limitations and future research

Our study does have certain limitations. Firstly, we use a cross-sectional data set, which does not allow us to test the impact of long term investments into certain capabilities. While we do fix the problem of common method bias through the use of a multiple respondent survey, future work should also focus on a longitudinal study that can capture the influence of time based investments into capability developments and their impact on supply chain risk. Secondly, although this study focuses on empirically examining environmental uncertainty as the key antecedent for supply chain risk and the use of supply chain flexibility as a risk mitigation tool, there could be other drivers of supply chain risk that require a different risk mitigation strategy. Further research could deal with a comprehensive understanding of the different drivers of supply chain risk, and empirically examining other risk mitigation strategies as moderating factors. Another limitation of this study is that we operationalize the risk constructs as a combined measure of probability and impact of the risk event. Future studies should focus on looking at the two risk measures separately as these two dimensions of risk may require different risk mitigation strategies.

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Appendix A. Questionnaire

A.1. Environmental uncertainty

To what extent do you agree with the following statements? (scale: 1 to 5 - (1) strongly dis-agree; (2) disagree; (3) somewhat agree/disagree; (4) agree; (5) strongly agree]).

1. Demand fluctuates drastically from week to week (EU1)
2. Total manufacturing volume fluctuates drastically from week to week (EU2)
3. Mix of products you produce changes drastically from week to week (EU3)
4. Supply requirements (volume and mix) vary drastically from week to week (EU4)
5. Products are characterized by a lot of technical modifications (EU5)
6. Suppliers frequently need to carry out modifications to the parts/components they deliver to your plant (EU6)

A.2. Supply flexibility

Indicate the current level of implementation of the following supply chain risk mitigation strategies (to be prepared for unexpected supply chain breakdowns) (scale 1–5).

1. Maintaining a flexible supply base (SCF1)

Indicate the current level of implementation of the following action programs (scale 1–5).

2. Developing collaborative approaches with key suppliers (e.g. supplier development, risk/revenue sharing, long-term agreements) (SCF2)
3. Joint decision making with key suppliers (about product design/modifications, process design/modifications, etc.) (SCF3)

A.3. Manufacturing flexibility

Indicate the current level of implementation of the following supply chain risk mitigation strategies (to be prepared for unexpected supply chain breakdowns) (scale 1–5).

1. Maintaining excess capacity (MF1)
2. Maintaining excess labour (MF2)
3. Product postponement (MF3)

A.4. Distribution/logistics flexibility

Indicate the current level of implementation of the following supply chain risk mitigation strategies (to be prepared for unexpected supply chain breakdowns) (scale 1–5).

1. Flexible modes of transportation (multi-modal, multi-carrier, multi-route transportation) (DF1)

Indicate the current level of implementation of the following action programs (scale 1–5).

2. Developing an international distribution strategy (e.g., open foreign sales office, develop an international distribution network) (DF2)

A.5. Supply risk

Risk management of the plant's dominant activity.
Please evaluate the probability of occurrence and impact of the following risks (Scale 1–5):

1. A key supplier fails to supply affecting your operations – probability (SR1)
2. A key supplier fails to supply affecting your operations – impact (SR2)

A.6. Manufacturing process risk

Risk management of the plant's dominant activity.
Please evaluate the probability of occurrence and impact of the following risks (Scale 1–5):

1. Your manufacturing operations are interrupted affecting your shipments - probability (MR1)
2. Your manufacturing operations are interrupted affecting your shipments – impact (MR2)

A.7. Delivery risk

Risk management of the plant's dominant activity.
Please evaluate the probability of occurrence and impact of the following risks (Scale 1–5):

1. Your shipment operations are interrupted affecting your deliveries - probability (DR1)
2. Your shipment operations are interrupted affecting your deliveries – impact (DR2)

A.8. Competitive intensity

How do you perceive the following characteristics of the environment in which your business unit operates? (Scale 1–5):

1. Market concentration (CI1)
2. Competitive rivalry within industry (CI2)
3. Market entry (CI3)

A.9. Preventive risk mitigation

Indicate the current level of implementation of action programs related to (Scale 1–5):

1. Preventing operations risks (e.g. select a more reliable supplier, use clear safety procedures, preventive maintenance) (PRM1)
2. Detecting operations risks (e.g. internal or supplier monitoring, inspection, tracking) (PRM2)

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