Uncertainty Assessment in Automotive Supply Chains

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Abstract

Supply chains in automobile industry are highly vulnerable and suffer huge losses due to uncertainty and risk. Literature suggests that losses can be reduced if these uncertainties are managed properly. Researchers have evolved a four-step process of risk management. Assessment of risk in terms of its probability of occurrence and impact on supply chains is one of the four steps. The present work is an attempt to empirically estimate the probability of different uncertainties to occur and also to determine their impact on supply chains. The study involves tier 1 and tier 2 level companies which manufacturer and supply auto components to various supply chains. The results are expected to help the industry prepare itself to reduce the impact of such uncertainties and improve the performance.

Keywords: Automotive Supply Chains, Assessment of Uncertainty, Probability-Impact Analysis

Introduction and Literature Review

Adopting the definition given in the seminal work by Knight (1921), Khan & Burnes (2007) view uncertainty and risk as related but not the same. They distinguish uncertainty from risk as the former may not be measurable, whereas, the latter is measurable and hence manageable. Ritchie & Brindley (2007), however, find risk and uncertainty being frequently used interchangeably. Simangunsong *et al*. (2012) also cite studies where researchers considered the line separating uncertainty from risk as so thin that they did not find it important to distinguish between the two. Though the focus of the present paper is on uncertainty, the authors have used the two terms interchangeably.

Christopher & Lee (2004) find it difficult for supply chains to be efficient if they are highly exposed to risk. The authors further argue that risks reduce the confidence of managers in supply chains and hence increase the expected loss in performance.It is clear from the literature that uncertainty hampers the performance of companies and hence that of their supply chains. For example, Wagner & Bode (2008) have conducted a survey in Germany to investigate the relationships between five risk sources (predictor variables) and supply chain performance (outcome variable) with risk management as the single control variable. The respondents of this study were top-level executives in logistics and supply chain management from manufacturing, service, and trade sectors. The five risk sources under study include demand side; supply side; regulatory, legal, and bureaucratic; infrastructure; and catastrophic risks. The demand side and supply side risks are found to have a significant negative impact on supply chain performance. Further, studies indicate that supply chain performance can be improved by managing and reducing uncertainty (Childerhouse & Towill, 2004; Punniyamoorthy *et al*., 2013). Such arguments emphasize the importance of managing risk and uncertainty in supply chains.

Christopher (2002) defines supply chain risk management (SCRM) as the management of external risks through a coordinated approach among the supply chain members to reduce supply chain vulnerability as a whole. Juttner *et al*. (2003) have proposed a four-step process to manage supply chain risk and uncertainty. The four steps are (1) assessing the risk sources, (2) defining the risk concept and adverse risk consequences, (3) identifying the risk drivers, and (4) mitigating the risks. This framework underlies the fact that risk management in supply chains is a chain-specific and/or industry-specific process. Therefore, supply chain managers need to identify, in their context, the sources and drivers of risk and uncertainty; understand the risks; estimate the possible adverse consequences of uncertainties; and accordingly adopt a suitable approach for risk mitigation. Several other authors have adopted this four-step (or a similar) approach in their work. Vanany *et al*. (2009), for example, suggest the following stages of a risk management process- identification of risk events, assessment of their probabilities and severity of impacts, prioritisation of the risk events to be dealt with, and development of actions for mitigating the risks.

Industry characteristics are among the major sources of risk (Ritchie & Brindley, 2007). The present work, a portion of a larger study conducted by the authors, limits its scope to the assessment step of the SCRM four-step framework applied to automotive supply chains.The context of the present work is justified because of the fact that automotive supply chains are among the most complicated chains to manage because of the involvement of enormous number of suppliers and the associated uncertainties. A small car, for example, consists of as many as 3000 components each of which is designed separately to work in perfect coherence with each other (www. auto.indiamart.com).Any disruption in the chain has a great impact on the performance of the entire chain. Maruti Suzuki India Ltd. has incurred a revenue loss of 15 billion rupees (US$306.7 million) as a result of the incident occurred in 2011 at the Maruti plant in Manesar (WSJ, 2011). The study involves tier 1 and tier 2 level companies which manufacturer and supply auto components to various supply chains.

Methodology

The portion of the study which is being presented here deals with the assessment of uncertainty in automotive supply chains using probability-impact matrix and ANOVA.

A conceptual framework of risk assessment, suggested by Steele & Court (1996), consists of three steps-determining the probability of an uncertain event occurring, estimating the likely duration of the event, and investigating its impact on the performance (Zsidisin *et al*., 2004). Zsidisin *et al*. (2004), while analysing various risk assessment techniques, find that all such techniques have a common theme of investigating the probability and impact of detrimental events. Probability in the context of SCRM is defined by Zsidisin *et al*. (2004) as a measure of how often a detrimental event that results in a loss occurs. Further, the impact refers to the significance of the loss. Accordingly, risk is perceived to exist when this probability and significance are both high.

After gaining an insight of the subject and industry through literature review, data are captured through a structured questionnaire administered to the respondents. 25 variables are identified from the literature as potential sources of risk and uncertainty in supply chains. The respondents were asked to indicate the probability of occurrence of these uncertainties and the magnitude of negative impact of such uncertainties with reference to their supply chains. A five-point Likert scale approach (Thun & Hoenig, 2009; Merschmann & Thonemann, 2011) has been used to receive responses on this issue.The questionnaire in its draft stage was discussed with two academicians in the field of supply chain management. Prior to starting the data collection, the questionnaire was also sent to five friends of the researchers who have been working in the automobile industry in India or abroad to assess its suitability as an instrument for actual data collection.

The questionnaire was administered to manufacturers of auto components using convenience sampling method at the Auto Exhibition held in New Delhi and Greater Noida (Uttar Pradesh) during February 6-11, 2014. An initial sample of 163 with a response rate of nearly 50 percent ended up to 84 responses. These questionnaires were then screened and edited to take care of inconsistent, erroneous, and incomplete responses, if any. Finally, 78 responses were found suitable to be included in the analysis.The sufficiency of this sample size is derived from previous studies where the initial size ranges from less than 100 to over 1000. For instance, Merschmann & Thonemann (2011), in their survey-based article on supply chain flexibility, uncertainty, and performance have analysed 32 responses received from an initial sample of 71 manufacturing companies.

Analysis and Results

The responses on 25 items of the questionnaire were first factor analysed in order to arrive at five sources of uncertainty in automotive supply chains- The five sources account for a cumulative 66 per cent of the total variance and are labeled as operational uncertainty (OPU), environmental uncertainty (ENU), demand-supply uncertainty (DSU), shop floor uncertainty (SFU), and logistics uncertainty (LGU). Details and results of the factor analysis followed by reliability and validity tests are beyond the scope of the present paper as it focuses only on the assessment part. However the following paragraph presents a brief description of each source.

Operational uncertainty consists of variables like inflexibility in handling changes in order contents and volume; inventory shortage; and inflexible/insufficient/ineffective networking with partners in the chain to take care of fluctuations from either upstream or downstream. Environmental uncertainty includes those sources of risk and uncertainty which are external to the supply chains and difficult to handle with in advance. Eight variables from downstream and upstream have constituted the demand-supply uncertainty. Shop floor activities in a company of any supply chain revolve around men and machines. They are also a major cause of accidents that take place in a company. The fifth source of uncertainty that is extracted from the data pertaining to automobile supply chains is the disruptions due to logistics.

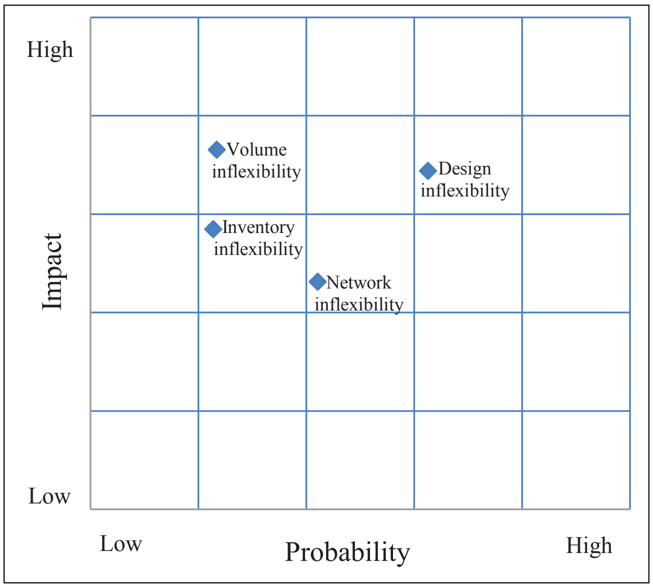
Probability-Impact Analysis

Probability-Impact matrix (Zsidisin *et al*., 2004; Thun & Hoenig, 2009) has been used in this study as a tool for the assessment of uncertainty. Each of the five sources of uncertainty are analysed separately using the probability and impact data collected on a five-point Likert scale, as explained in the previous section. For all variables of a source, the average probability and impact are calculated to be considered as the coordinates of the variables for probability-impact (P-I) matrix. This probability and impact was measured for each variable using a five-point scale running from very low through low, moderate, high to very high. Each source of uncertainty is presented separately through Figure 1 – 5.

From Figure 1, it is evident that in automobile supply chains, inflexibility of production systems to handle changes in order contents/design is relatively the most frequently occurring source of (operational) uncertainty. Whereas, the volume inflexibility (inflexibility of a production system to respond to changing volume of demand) poses the highest threat (in terms of impact) to such supply chains in this category of uncertainty.

Figure 2 represents the P-I matrix for the variables under environmental uncertainty. The figure suggests that the automobile industry is highly technologically volatile in terms of technology. Technological turbulence in the industry even leads to changes in supply chain configurations- new suppliers might replace the existing ones due to rapid changes in technology. Social disruptions like strikes and terrorist attacks, though occur less frequently, result in serious consequences. Changes in economic environment are the next important source of environmental uncertainty. It is obvious that changes in inflation, interest rate, and economic policies disturb the functioning of supply chains, particularly with reference to import and export. Changing norms and policies related to automobile industry and changes in political environment of the country are another deterrent for supply chains but with relatively low probability and low impact.

Figure 1: Probability-Impact Matrix for Operational Uncertainty



The eight variables of demand-supply uncertainty (Figure 3) have a mixed effect and likelihood of occurrence. Among the upstream side variables, delayed supplies and variations in lead time are the most likely events to occur and also impact the chains to a large extent. Suppliers very often receive requests from their customers to expedite the delivery which is found to have a great impact on supply chains. Market turbulence in terms of unpredictable demand volume and changes in order contents or design add to disruptions from the downstream. If one estimates the loss to supply chains in terms of the product of probability and impact of any uncertainty, the demand side generates a mean loss of 8.07 as against the supply side mean of 8.19. These results are supported by Wagner & Neshat (2010), who have determined that demand side has a lower vulnerability than the supply side in automobile industry.

Figure 2: Probability-Impact Matrix for Environmental Uncertainty

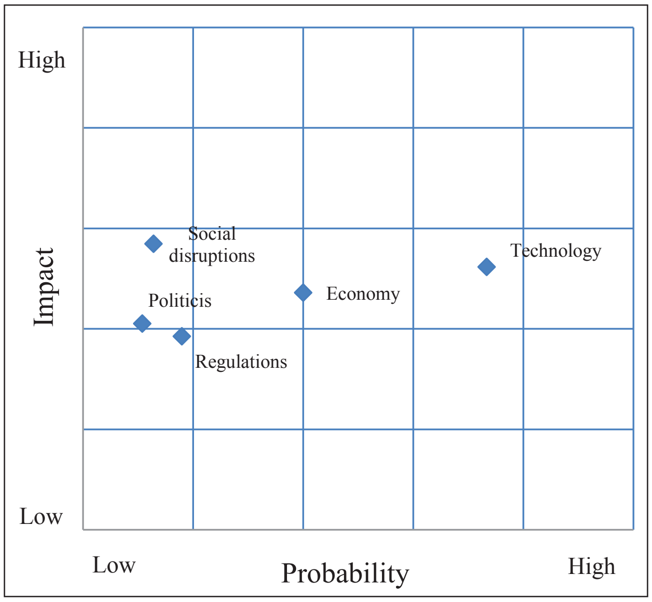


Figure 3: Probability-Impact Matrix for Demand-Supply Uncertainty

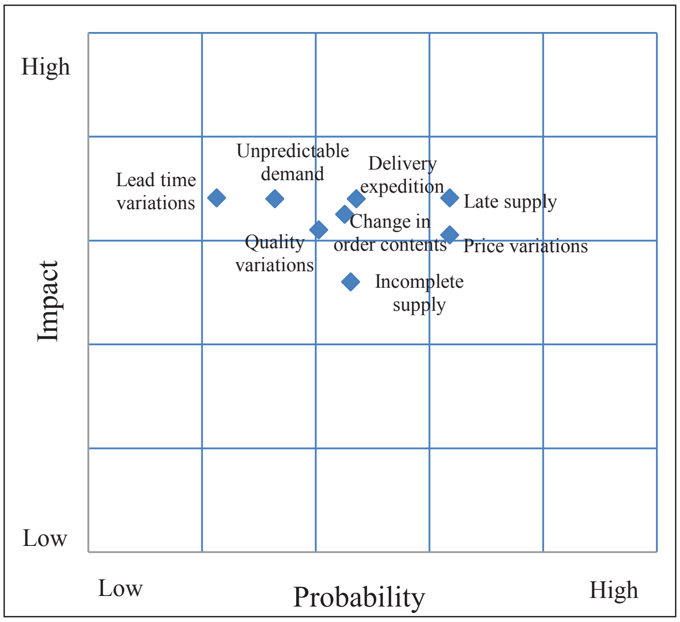


Figure 4 and 5 are the P-I matrices for shop floor and logistics uncertainty respectively. Machine breakdowns have got relatively higher probability and impact as compared to labour problems and shop floor accidents. Supply side disruptions in logistics are found to have more serious consequences with higher frequency than those on the distribution side.

Figure 4: Probability-Impact Matrix for Shop Floor Uncertainty

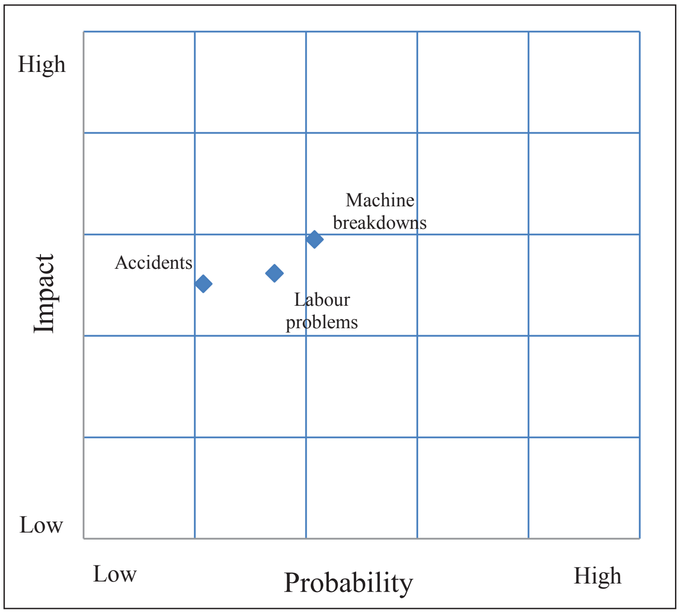
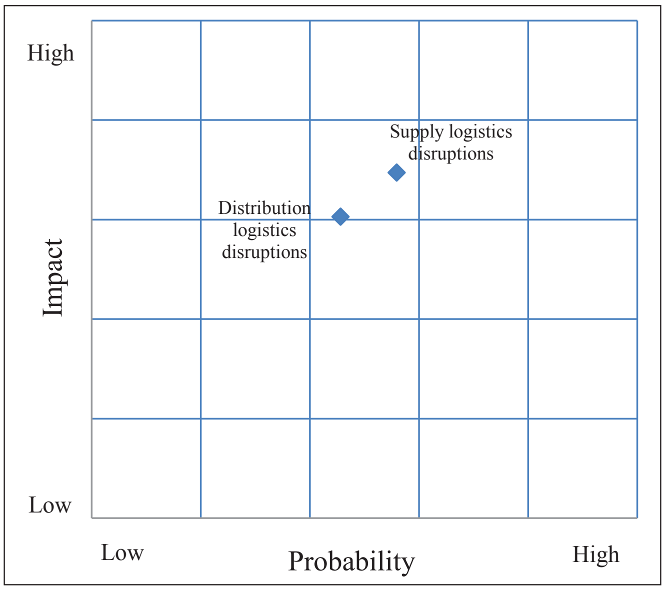


Figure 5: Probability-Impact Matrix for Logistics Uncertainty



To sum up, the P-I matrix for the five sources of uncertainty is presented in Figure 6. From the figure, it is understood that automobile supply chains are more susceptible to logistics and demand-supply uncertainties than the shop floor, operational, and environmental sources of uncertainty.

Table 1: Mauchly's Test of Sphericity

Within Subjects Effect	Mauchly's W	Approx Chi-Square	df	Sig.	Epsilon		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Uncertainty	.686	28.403	9	.001	.853	.897	.250

Figure 6: Probability-Impact Matrix for Uncertainty Sources

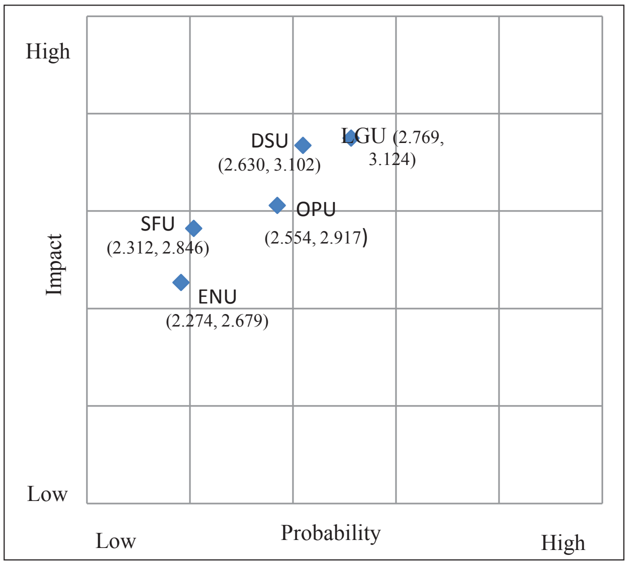


Table 2: Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Uncertainty	Sphericity Assumed	10.687	4	2.672	5.405	.000
	Greenhouse-Geisser	10.687	3.412	3.132	5.405	.001
	Huynh-Feldt	10.687	3.590	2.977	5.405	.001
	Lower-bound	10.687	1.000	10.687	5.405	.023
Error(Uncertainty)	Sphericity Assumed	152.248	308	.494		
	Greenhouse-Geisser	152.248	262.737	.579		
	Huynh-Feldt	152.248	276.398	.551		
	Lower-bound	152.248	77.000	1.977		

Statistical Analysis

From the P-I analysis of each source of uncertainty (Figure 6) it is found that the five sources have different frequencies of occurrence and also have different magnitudes of impact on supply chains. These observations are tested for their statistical significance using repeated-measures design of ANOVA. The null hypothesis for this purpose is formulated as "each source of uncertainty has equal impact on supply chains". Each respondent (company) represents a separate supply chain, the five types of uncertainty are treated as five different levels of treatment (independent variable), and the impact under each condition (of uncertainty) acts as the dependent variable. The value of the dependent variable for each respondent under each uncertainty is obtained by averaging his/her impact scores on all variables (items) of that factor. For example, the average of impact scores of respondent 1 on variables 14, 17, and 18 is the value of the dependent variable for respondent 1 under shop floor uncertainty.

The first step in repeated-measures ANOVA is to see whether the assumption of sphericity has been met by the data. Sphericity refers to the equality of variances of the differences between treatment levels (Field, 2005). The null hypothesis to test sphericity is that differences have equal variances and the result should be non-significant to proceed further. The test when run on the data returns the Mauchly's W statistic as 0.686 with $p< .05$ (Table1), which indicates that the assumption of sphericity is not met. Step 2 in such cases is to analyse the corrections (Table 2). The ANOVA produces the corrected F value as 5.405 which is significant ($p< .05$). Thus the results confirm the findings of the P-I analysis that different sources of uncertainty produces different impact. Further, the mean impact under condition of environmental uncertainty is found statistically different from that under logistics and demand-supply disruptions.

Conclusions

Supply chains in automobile industry are exposed to various risks and uncertainties because of their complexity and competitiveness. Despite being widely researched, uncertainty issues in automobile supply chains still need attention. The present work is an attempt to empirically estimate the probability of different uncertainties to occur and also to determine their impact on supply chains. Five sources of uncertainty are found consisting of 22 components. The five sources, namely, operational, environmental, demand-supply, shop floor, and logistics are analysed using probability-impact matrix and

ANOVA. It is found that (a) the five sources of uncertainty occur in different frequencies and impact differently, and (b) demand-supply elated variations and logistics disruptions have higher negative impact on supply chains as compared to other three types of uncertainties. The results are expected to help the industry prepare itself to reduce the impact of such uncertainties and improve the performance.

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