Managing the Supply Risks in Green Supply Chain using Monte Carlo Simulation

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Abstract

Green supply chains consist of a set of various process and activities related to its supply, i.e. at supplier end in business. Different activities at supplier end may involve different risks and risk factors and or drivers in GSC, which may decrease the overall performance. In this paper, we attempt to focus on the supply GSC risk evaluation and management by capturing of the uncertainty and evaluating the risks by means of simulation to demonstrate the delay/disturbance impacts of the risk (i.e., the loss in business). This work follows a procedure in which, initially, the various uncertainties have been identified and assessed. Later, a risk evaluation has been followed in which the Monte Carlo Simulation (MCS) results illustrate the delay/disturbance impacts of the risk is conducted. The inputs in this research are taken from the case example of an Indian poly plastic manufacturing company. The paper ends with some concluding remarks.

Keywords: Green Supply Chain, Monte Carlo Simulation, Supply Risk, Uncertainty, Sensitivity Analysis

1. Introduction

The phenomena of green supply chain (GSC) have got an increased attention all over the globe among organizations (Mangla,et al. 2012, 2013, 2014a, 2014c). Every business activity in GSC, however, consists of various risks and risk factors and or drivers (Ruimin et al. 2012; Mangla et al. in press). The occurrence of the different risk will impact the system adversely, and even results loss in business, if managers do not account them on timely (Mangla et al. 2014b). Thereby, in order to effectively managing the GSC, it is significant to argue on the concept of the risks in GSC (Mangla et al. 2014d).

The current research context focuses the supply GSC risk evaluation and management by capturing of the uncertainty and analyzing the risks by means of simulation to demonstrate the disruption impacts of the risk (i.e., the loss in business). The uncertainties are identified and assessed, and a risk evaluation follows in which the Monte Carlo Simulation results illustrate the disruption impacts of the risk is conducted. The GSCM case study example of an Indian poly plastic manufacturing company is discussed in the research. The reason of conducting this case study is to scientifically analyze and evaluate the risks affecting the GSC under study in terms of the nature of their impact.

The remaining of this paper is set out as follows. Section 2 describes the supply risk in the context of GSC. In Section 3, the proposed model for this research is presented. Section 4, presents the case study along with the application of proposed model to the discussed case. Finally, conclusions and directions for future research are presented in Section 5.

2. Supply risks in the context of GSC

Risk, which an unavoidable phenomenon, is recurring in almost all activities, and accordingly, affecting the system respective process, operations etc (Waters 2007). Concerning to supply chain system, for a holistic view, it is crucial to have knowledge on risk understanding and how to manage them can be greatly beneficial for managers to reduce their consequences (Juttner 2005). Given that, GSC is stated as the combination of set of activities of SC that includes environmental component in its each and every stage (Srivastava 2007; Mangla et al. 2013).

In domain of supply chain management, according to literature, risk is all about 'disruption or disturbance' in various activities of supply chain and that results to some undesired happenings or consequences (Harland et al., 2003).

Supplying appropriate environmental friendly material (green raw material or recycled material) for producing the finished green product is an important function of the organizational GSC as any disruption in supply might reduce their ecological-economic gains (Mangla et al. in press). The supply risks in GSC context can be defined as the risk of loss resulting from loss or failure of suppliers, their policies, quality, delivery etc.

To manage the consequences, it is needed to include the risk management practices in the plans of GSCM (Mangla et al., in press). There is therefore a framework is proposed in this research, whose details are given in next section.

3. Proposed model

Based on the critical review of literature and expert's judgments, the supply risks and its risk driving factors in GSC context have been identified. These risks were evaluated using industry expert judgments. Whilst, to analyze the risk impacts that measured in time in terms of delay/disturbance (i.e. business loss), a simulation based approach of Monte Carlo Simulation (MCS) was used. However, the proposed model for this research work is illustrated in Figure 1 shown below.

4. A case study example

To fulfill the purpose of this work, we have identified an Indian GSCM case firm example. The firm is well-established and has a distinguished place in plastic manufacturing sector. The managers of firm are seeking to identify and evaluate risks at supplier end in GSC at shop floor level, which will help them in gaining high profits. To meet this, the proposed model is applied to the example discussed initially in the section.

A source of literature is used to identify the supply risk drivers or sources for GSC in question. To make it more authentic and reliable, the expert group from the case GSC has also been consulted. Thus, based on literature and expert opinion, a total of four supply risk factors selected (see Table 1). After identifying the risk, we evaluated these risks in order to determine their consequences on the green supply chain. On discussion with experts, the probability of occurrence of the identified risks and their consequences were analyzed as

shown in Table 1. The risk consequences were classified into five dimensions Time, Brand image, Economic, Health and Safety, Quality etc.

This delay/disturbance impact was modeled in the form of triangular distributions (Vilko and Halikas 2012). Prior to this, a scale that analyzes the likelihood and impact of the risks is designed (for details please see Table 2). After this, the expert's response with respect to the green supply chain risk drivers and their impacts on considered aspects were obtained as shown in Table 3. Finally, a risk score (RS), as shown in last column of table is calculated. Further, to model the delay impact of the identified risks, the simulation approach is used. To feed the inputs needed for Monte Carlo Simulation, the same expert group was used. Graphical version @Risk is used to perform the required computations and computes the risks and uncertainties.

Then, we have computed the probability measure for each risk in corresponds to its risk-likelihood measure as shown in Table 2. Next to this, single simulation and 20,000 iterations were used to analyze the uncertain conditions for the GSC under study, and the outcome is shown in Figure 2. An advanced sensitivity analysis test (Sensitivity Tornado) has also been performed to determine the consequence of inputs (risks) on the mean of the output as shown in Figure 3. It can be clearly deduced that the ranking or preference order in terms of their consequence on output mean is given as S3 – S2 – S4 – S1.

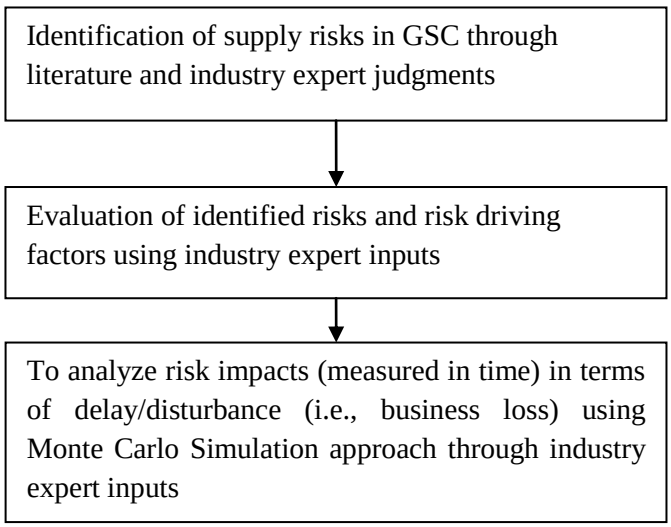

Figure 1. Proposed model

Table 1. Supply risks and their consequences

Description	Probability	Time		Brand image	Economic	Health and Safety	Quality	Risk score (RS)
		Delay/disturbance	Disruption	Damage	costs	harm	Unfavorable/ poor	
Procurement costs risks (S1)	1	1	1	1	3	0	1	7
Key supplier failures (S2)	3	5	9	9	5	0	3	93
Supplier quality issues (S3)	5	3	5	5	3	3	3	110

Green raw-material supply disruptions (S4)	3	3	3	3	5	0	1	45

Table 2. Linguistic scale

Linguistic scale	Description	Corresponding probability value in terms of % (through expert opinions)
1	No/minor	.0001
3	Low	.0045
5	Moderate	.0025
9	High	.01

Table 3. Summary on likelihood of delay/disturbance and its impact in GSC under study

Description	Probability of occurrence	Delay/disturbance in terms of time (days)		
		min	average	max
Procurement costs risks (S1)	0.0001	0	0.5	1
Key supplier failures (S2)	0.0045	1	4	7
Supplier quality issues (S3)	0.0025	1	40	90
Green raw-material supply disruptions (S4)	0.0045	0.25	0.5	1

5. Concluding remarks

The contribution of this work is twofold: firstly, to identify and assess the risks affecting the supplier end at GSC, and secondly, to analyze the impact of the risks in terms of delay. Based on the combined review of literature and inputs received from the experts, a total four supply risks in GSC are identified and evaluated to access their consequences in terms of Time, Brand image, Economic, Health and Safety, Quality etc. The maximum impacts were seen in time based consequences and that was measured in terms of time delays/disturbances and disruptions. Further, the human based assessment unable to give extreme scenario and so, Monte Carlo Simulation is used. In addition, it also helps to capture the uncertainties in the inputs. It has been believed that this study provides valuable information for the managers of the case company to access and manage supply risks in their GSC design to reduce and manage their consequences.

The finding of this research primarily depends upon the knowledge and experience of expert, which may distort the process of decision-making due to human bias. Therefore, some measures may be taken in the future studies to overcome the human subjectivity.

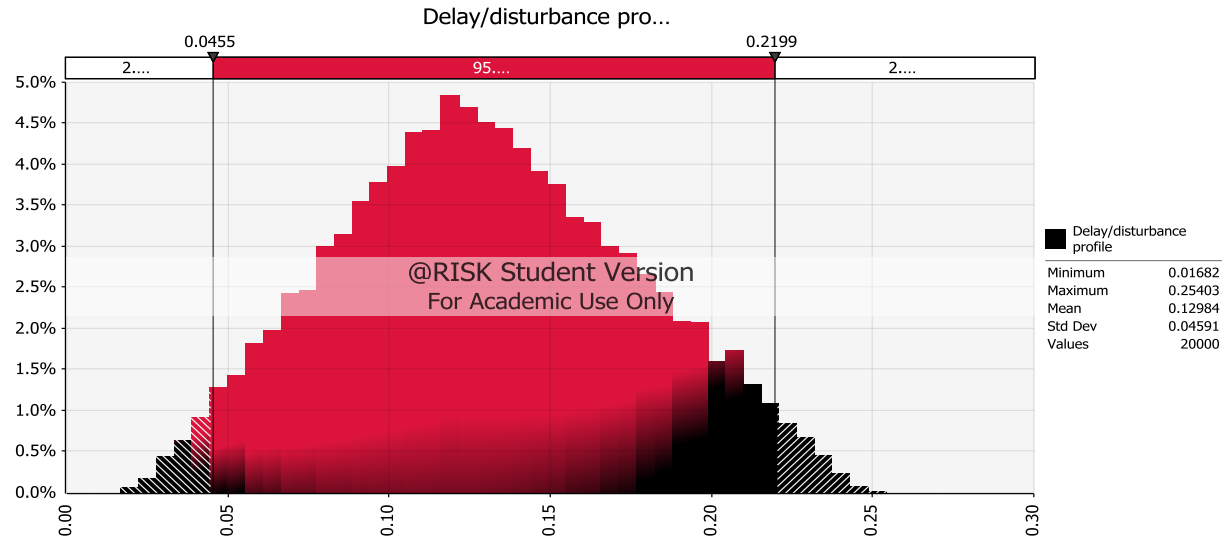

Figure 2. Simulation result of risk consequences

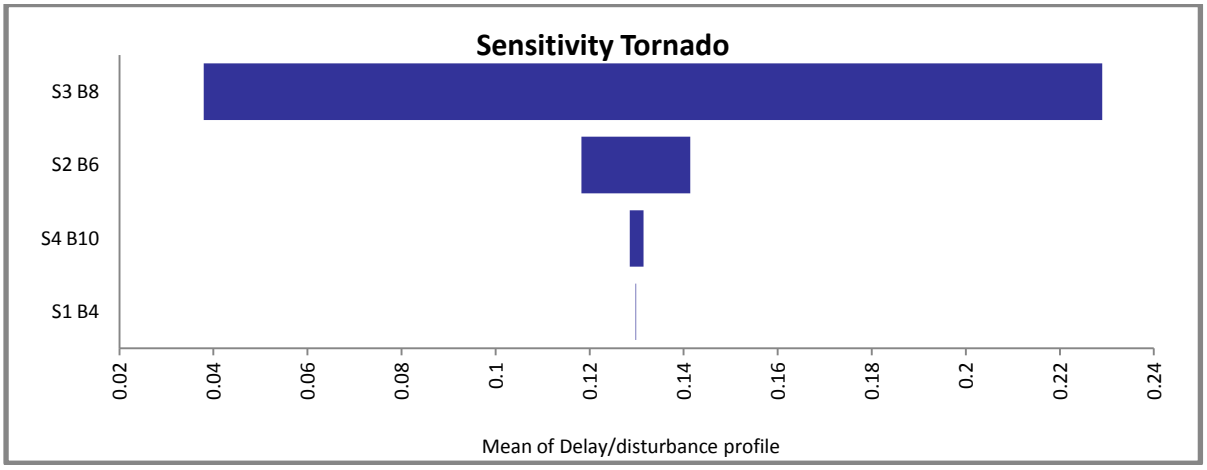

Figure 3. Sensitivity analysis result of mean of delay/disturbance profile

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