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Prioritization of Risks in Bicycle Supply Chain Using TOPSIS

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Abstract: ***Globalization has greatly increased the supply chain risk and its impact. The endless efforts to improve responsiveness and reduce costs has created new kinds of supply chain risks. Many companies have recognized this and are now undertaking supply chain risk management programs. This work deals with the prioritization of eight supply chain risks identified through literature and expert opinion using Multi Criteria Decision Making (MCDM) technique Integrated approach of Technique for Order Preference by Similarity to Ideal Situation (TOPSIS) for a bicycle manufacturing company***.

Keywords: Supply chain Management, Risk Management, TOPSIS, Prioritization

1. Introduction

The supply-chain management (SCM) has become very critical to manage risk, dynamism, and complexities of global sourcing. A totally integrated supply chain is required for the company to get gain the maximum benefits. Supply Chain Management (SCM) has emerged as one of the principal areas on which leading edge companies are focusing to increase market share, profitability, competitive advantage and shareholder value.

The definition evolution continues as European Logistics Association, in 1995 suggested SCM was, "The organization, planning, control and execution of the goods flow from development and purchasing through production and distribution to the final customer in order to satisfy the requirements of the market at minimum cost and minimum capital use". Supply chains are exposed to a variety of risks that are unique to each supply chain. These risks are related to actions and events that are inside and outside of the supply chain. Supply chain risk analysis seeks to identify these risks, their sources and drivers and their impact on the supply chain. The objective of this work is to identify various risks in the bicycle supply chain and rank those using Multi Criteria Decision Making (MCDM) technique called Technique for Order Preference by Similarity to Ideal Situation (TOPSIS).

2. Literature Review

This section deals briefly the review of literature related to risks in supply chain and Multi criteria Decision Making (MCDM) techniques which support the decision-makers (DMs) in evaluating a set of alternatives. Depending upon the situations, criteria have varying importance and there is a need to weigh them.

Wu (2007) deals with the supplier selection problem, The author discussed a class of AHP (analytical hierarchy process) technique—simulation approach, which is valuable in that it examines the uncertainty in AHP and helps to reduce the uncertainty in AHP to some extent.

Salunke et al (2009) focused in identify the risks involved in the reverse supply chain. For the collection of data and information required for analysis they used Survey tool. The methodologies that are used to identify key risks are the six sigma tools namely Define, Measure, Analyze, Improve and Control (DMAIC), Cause and Effect, and Risk Mapping. After the analysis the key risks are identified and the above mentioned six sigma tools are used to developed solutions to mitigate the major risks in reverse supply chain.

Mahendran et al (2011) investigated the types and management of risks faced within the supply chain functions of an Indian pharmaceutical company. The research was done through a case study approach. The author highlighted the risks faced in the pharmaceutical company and also identifies the critical point in each section of the supply chain and also investigated the mitigation strategies for dealing with these risks. The critical points at different stages of the supply chain have been identified through a survey and the main reason for the risk has also been investigated.

Pires et al (2011) had done a study to integrate the Analytic Hierarchy Process (AHP) and the TOPSIS for alternative screening and ranking to help decision makers in a Portuguese waste management system. To underscore the role of uncertainty in decision making for alternative ranking, a fuzzy interval multi-attribute decision analysis was carried out to aid in environmental policy decisions. While AHP was used to determine the essential weighting factors, screening and ranking was carried out by TOPSIS under uncertainty expressed by using an interval-valued fuzzy (IVF) method.

Krisnawati et al., (2018) analyzed the pattern of five supply chain flow models and its 21 risks, in which 11 of them were mitigated. They also implemented ISO 31000:2009 to mitigate the risks. Jiang et al., (2017) use Matlab to simulate the transmission model in which relation between supply chain enterprises was determined. It also suggested that credit risk of core enterprise need to be paid attention. Tunc et al., (2017) revealed the key risk management strategies responsible for increased company sales. They also provided a comprehensive understanding of supply chain risk management using quantifying data mining approach. Kraude et al., (2018) explored the relationship between environmental and location or cultural factors in three countries by conducting a survey. In this process, they showed that Japan has a higher level of perceived SCR and lower application of risk mitigation strategies than two western culture countries, the USA and Australia. Kotula et al., (2018) found that risk management has not been adopted fully across industries and countries from a strategic sourcing perspective in Germany and the United Kingdom. They also present several significant insights for managing risks in strategic sourcing.

Yiyi Fan and Mark Stevenson (2018) done a detailed review of 354 articles on supply chain risk management, in which they emphasized organizational responses to supply chain risks and made only limited use of theory. Baryannis et al., (2018) conducted an investigation on the various definitions and classifications of supply chain risk and related notions such as uncertainty and applied Artificial Intelligence (AI) techniques in SCRM. This study gives directions for future research at the confluence of SCRM and AI. Hariharan and Rajmohan (2015) applied MCDM techniques such as AHP, FAHP and TOPSIS in prioritizing the supply chain risks in a bicycle manufacturing company. From there study they found that supply risk has a major impact in the supply chain. Joshua Kiptum and Barack Okello (2018) examine the influence of purchasing risk management on supply chain performance of manufacturing firms in Nakuru County, Kenya. Supply assurance from the suppliers and improper supplier selection were the key terms to be addressed to ensure improvement in supply chain performance. Jeroen et al., (2018) focused on the relationship between a service provider and a customer that acted on behalf of other users in the defense sector. The service provider's performance attributability appeared to have a strong impact on its willingness to take PBC-induced risks. The service provider's willingness to accept PBC-induced risks was also affected by its ability to make accurate forecasts, the applied growth path and the length of the contract.

3. Methodology

This section explains the methodology followed in this work to identify the critical risks in the bicycle supply chain. In MCDM, a problem is affected by several conflicting factors in selection, for which a manager must analyze the tradeoff among the several criteria. TOPSIS is a structured technique for dealing with complex decisions. TOPSIS helps decision makers to find one that best suits their goal and their understanding of the problem. TOPSIS is one of the most widely used tool since its invention, has been a tool at the hands of decision makers and researchers.

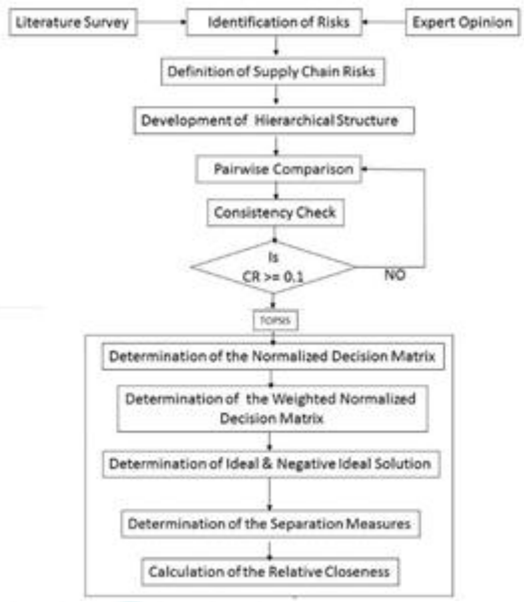

Figure 1: Schematic Diagram for Prioritizing the Supply Chain Risk

4. Case Study

The developed model is applied to a bicycle manufacturing company located in southern part of India. A supply chain of particular brand is selected for implementation of the methodology shows in figure 1. In this case, eight risks in the supply chain are considered and prioritized with corresponding sub risks. This section provides the steps needed to calculate the priority value to rank the supply chain risk using TOPSIS for the case study considered.

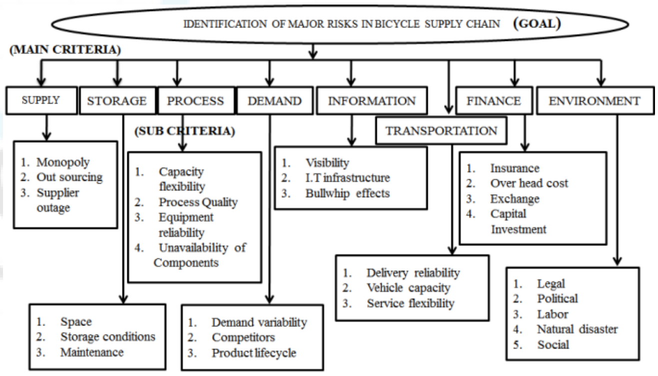

Figure 2: Hierarchy Structure for Prioritizing Supply Chain Risks

Eight risks namely Supplier, Storage, Process, Demand, Information, Transportation, Finance and Environment were identified as the relevant risks for this case through literature and expert opinion. The definition of each risk is given below.

1. Supply Risk (SU) - All issues with the movement of materials into an organization, including sources, supply market conditions, constraints, limited availability, supplier reliability, lead times, material costs, delays, etc.,
2. Storage Risk (ST) - Lack of care in maintaining quality, space lacking for storage.
3. Process Risk (PR) - Risks from product features, product

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mix, range, volumes, materials used and standardization.

4. Demand Risk (DE) - All aspects of customer demand, such as level of demand, variability, alternative products, competition and patterns of change.
5. Information Risk (IN) - Includes the availability of data, data transfer, accuracy, reliability, security of systems.
6. Transportation Risk (TR) - Movements of materials, including risks to the infrastructure, vehicles, facilities and loads.
7. Finance Risk (FI) - all money transactions, including payments, prices, costs, sources of funds, profit and general financial performance.
8. Environment Risk (EN) - Risks that are external to the supply chain.

Figure 2 shows the Hierarchical model where various risks in supply chain were categorized to the eight main risk factors.

A five step approach for TOPSIS applied to the case example is discussed.

Step 1: Calculate normalized decision matrix
Step 2: Weighted normalized decision matrix
Step 3: Determine the ideal and negative-ideal solution
Step 4: Determine the separation measures from ideal and negative ideal solutions
Step 5: Calculate relative closeness to the ideal solution

4.1 Step 1: Calculate normalized decision matrix

The normalized value r is calculated using the equation (1).

$$R_{ij} = \frac{X_{ij}}{\sum_{i=1}^{m} X_{ij}}, i = 1,\ldots.., m; j = 1,\ldots..n. \quad (1)$$

Normalized decision matrix is shown in the Table 1

Table 1: Normalized decision matrix for TOPSIS

C	*SU 0.26*	*ST 0.04*	*PR 0.23*	*DE 0.13*	*IN 0.06*	*TR 0.13*	*FI 0.08*	*EN 0.07*
SU	0.01	0.04	0.02	0.03	0.02	0.03	0.03	0.05
ST	0.003	0.01	0.003	0.003	0.005	0.005	0.005	0.003
PR	0.005	0.03	0.01	0.03	0.04	0.03	0.03	0.05
DE	0.003	0.03	0.003	0.01	0.02	0.02	0.03	0.02
IN	0.005	0.02	0.003	0.005	0.01	0.003	0.005	0.005
TR	0.003	0.02	0.003	0.005	0.04	0.01	0.03	0.04
FI	0.003	0.02	0.003	0.003	0.02	0.003	0.01	0.02
EN	0.002	0.03	0.002	0.005	0.02	0.003	0.005	0.01

Step 2: Weighted normalized decision matrix (V ij)

The weighted normalized value Vij is calculated using equation (2). Weighted normalized decision matrix is also calculated.

$$V_{ij} = W_i * R_{ij}, j = 1,\ldots.., J; i = 1,\ldots.n \quad (2)$$

Where, W_i -Weight of the i[th] Criterion, $\sum_{i=1}^{m} W_i = 1$

Weighted normalized decision matrix is shown in Table 2.

Table 2: Weighted Normalized decision matrix for TOPSIS

C	*SU*	*ST*	*PR*	*DE*	*IN*	*TR*	*FI*	*EN*
SU	0.003	0.002	0.005	0.004	0.001	0.004	0.002	0.004
ST	0.001	0.0004	0.001	0.0004	0.0003	0.001	0.0004	0.0002
PR	0.001	0.001	0.002	0.004	0.002	0.004	0.002	0.004
DE	0.001	0.001	0.001	0.001	0.001	0.003	0.002	0.001
IN	0.001	0.001	0.001	0.001	0.001	0.0003	0.0004	0.0003
TR	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.003
FI	0.001	0.001	0.001	0.0004	0.001	0.0004	0.001	0.001
EN	0.001	0.001	0.001	0.001	0.001	0.0003	0.0004	0.001

Step 3: Determine the ideal and negative-ideal solution

Ideal and negative ideal solutions are calculated using equations (3) and (4).

Ideal Solution $A^* = \{V_1^*, V_2^*, \ldots.., V_n^*\}$ (3)
$= Max_j V_{ij} \forall i$

Negative Ideal Solution $A^- = \{V_1^-, V_2^-, \ldots..V_n^-\}$ (4) $= \{\min_j V_{ij}\} \forall i$

Table 3 shows the ideal and negative ideal solution values for all criteria.

Step 4: Determine the separation measures from ideal and negative ideal solutions

The separation measures from ideal and negative ideal solutions are calculated using the n dimensional Euclidean distance concept. The separation of each alternative from the ideal solution (Dj*) is calculated using equation (5) and separation of each alternative from the negative ideal solution (D j ¯) is calculated using equation (6).

$$D_j^* = \sqrt{\left\{\sum_{i=1}^{n} \left(V_{ij} - V_i^*\right)^2\right\}}, j = 1,\ldots.., J \quad (5)$$

$$D_j^- = \sqrt{\left\{\sum_{i=1}^{n} \left(V_{ij} - V_i^-\right)^2\right\}}, j = 1,\ldots.J \quad (6)$$

Tables 3 show the separation measures from ideal and negative ideal solutions.

Step 5: Calculate relative closeness to the ideal solution

Relative closeness to the ideal solution (Cj*) gives the score of each alternative j. The relative closeness of the alternative j with respect to A* is given by equation (7).

$$C_j^* = \frac{D_j^-}{\left(D_j^* + D_j^-\right)}, \, j = 1,...., J \quad (7)$$

The TOPSIS scores are given in Table 3 and ranking obtained are shown below.

The most prioritized risks through AHP in desending order are given below.

Table 3: Ideal, Negative Ideal, closeness to the ideal solutions

C	*Vi+*	*Vi-*	*Si+*	*Si-*	*Ci*	*Rank*
SU	0.003	0.0005	0.001	0.008	0.86	1
ST	0.002	0.0004	0.008	0.001	0.06	8
PR	0.005	0.0005	0.003	0.007	0.72	2
DE	0.004	0.0004	0.006	0.004	0.39	4
IN	0.002	0.0003	0.008	0.001	0.11	7
TR	0.004	0.0003	0.006	0.004	0.40	3
FI	0.002	0.0004	0.007	0.002	0.19	5
EN	0.004	0.0002	0.008	0.001	0.15	6

Ranking of Main Criteria:

MAIN CRITERIA LOCAL WEIGHT

SUPPLIER 0.87
PROCESS 0.72
TRANSPORTATION 0.4
DEMAND 0.39
FINANCE 0.19
ENVIRONMENT 0.15
INFORMATION 0.11
STORAGE 0.0

Similarly by following the same procedure as main risk, weights of sub criteria also be calculated. By multiplying the local weights of each sub risks with corresponding main risks, the global weight of each risk will be obtained as shown below.

Ranking of Sub Criteria:

MAIN CRITERIA G. WEIGHT

Monopoly 0.87
Equipment reliability 0.72
Delivery reliability 0.4
Demand variability 0.39
Process quality 0.39
Capacity flexibility 0.2
Out sourcing 0.191
Over head cost 0.19
Service flexibility 0.156
Legal 0.15
Bullwhip effects 0.11
Natural disaster 0.077
Insurance 0.072
Storage conditions 0.06
Product lifecycle 0.05
Visibility 0.04
Maintenance 0.03
Political 0.027
Social 0.027
Exchange 0.024
Supplier outage 0
Competitors 0
Vehicle capacity 0
Unavailability of components 0
IT infrastructure 0
Labor 0
Capital investment 0
Space 0

Supply risk is identified as the most primary risk followed by process risk and the storage risk is ranked as the least important risk among the eight risk considered in this study. As for as the sub risks, Monopoly is identified as the most primary risk followed by Equipment reliability risk and Supplier outage, Competitors, Vehicle capacity, Unavailability of components, IT infrastructure, Labor, Capital investment, Space risks were ranked as the least important risks.

5. Conclusion and Future Work

In current dynamic environment risk management became an extremely important activity in supply chain management. In this work, MCDM techniques TOPSIS was adopted to rank the critical supply chain risk for a bicycle manufacturing company. Eight important supply chain risks were identified as significant risk for the case considered. Supplier risk found to be the most important one and Supplier outage, Competitors, Vehicle capacity, Unavailability of components, IT infrastructure, Labor, Capital investment, Space risks were given the least priority. In future, for the same case other MCDM techniques like FAHP, DEMATEL and Fuzzy TOPSIS can be applied to guide decision makers.

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