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Risk Assessment in Automobile Supply Chain

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Abstract

One of the challenges that have gained industry's attention is assessing supply chain risks with increasing exposure to disruptions, it is vital for supply chains to manage risks proactively. Across industries, one-third of all supply chains fail to manage risk on a formal basis. The story is slightly worse for automotive companies, with 37 percent acknowledging no formal practices for monitoring risk. Automotive companies trail top supply chains in implementing risk management practices. Prediction of potential failure points and overall impact of these risks is challenging. In this research, we aim to assess the major risks that are encountered in supply chain of automobile industry. The purpose of this paper is to develop a holistic, systematic and quantitative risk assessment for measuring the overall risk behavior. We have used FAHP modeling and further analysis is carried out using Chang's Extent Analysis Technique. A systematically developed design can be employed to capture the dynamic behavior of risks.

Keywords: Supply Chain,Risk Assesment,AHP,Pair-wise comparision matrix,FAHP,Change extent Analysis

Introduction

A supply chain is a system of organizations, people, activities, information, and resources involved in moving a product or service from supplier to customer. Risk assessment is defined as the process of analyzing the vulnerability to threats and recommending solutions to reduce the level of risk to an organization. The risk

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assessment process thus covers the most critical function of risk management [11]. Analytical hierarchy process was used to model supply chain risk assessment [4, 5].

Supply chain is a set of firms that pass materials forward. Normally, several independent firms are involved in manufacturing a product and placing it in the hands of the end-user in a supply chain — raw material and component producers, product assemblers, wholesalers, retailer merchants and transportation companies are all members of a supply chain [15]. By the same token, define a supply chain as the alignment of firms that brings products or services to market. Note that these concepts of supply chain include the final consumer as part of the supply chain [16].

Another definition notes a supply chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer [11].

Various other definitions of a supply chain have been offered in the past several years as the concept has gained popularity. The basic supply chain is as shown in figure 1.

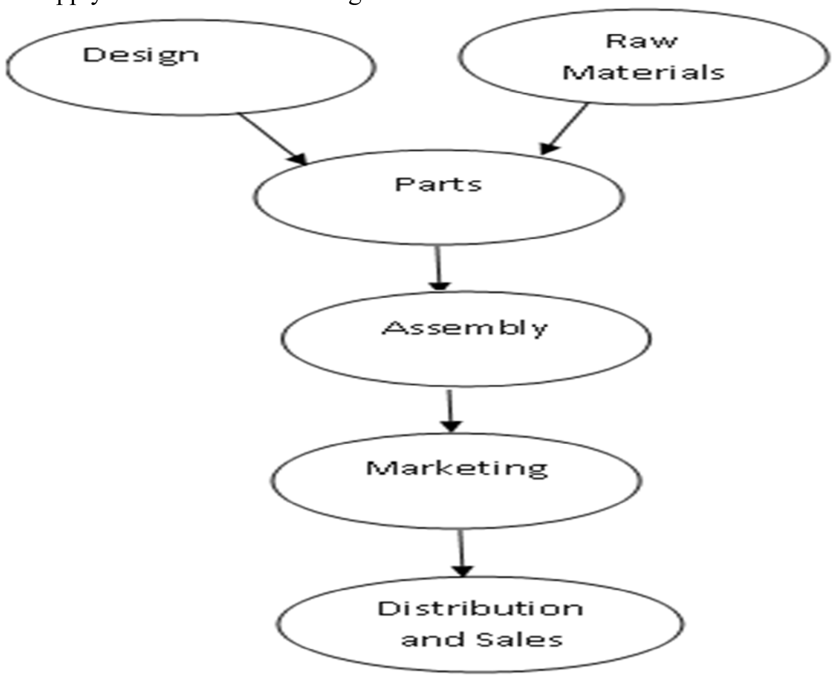

Fig.1. Supply chain of Automobile Industry

- The processes from the initial raw materials to the ultimate consumption of the finished product linking across supplier-user companies; and
- The functions within and outside a company that enable the value chain to make products and provide services to the customer [24].

In most of the real-world problems, some of the decision data can be precisely assessed while others cannot. Humans are unsuccessful in making quantitative predictions, whereas they are comparatively efficient in qualitative forecasting [25]. These applications are performed with many different perspectives and proposed methods for fuzzy AHP. In this study, extent analysis on fuzzy AHP is formulated for a selection problem [26].

The fuzzy AHP technique can be viewed as an advanced analytical method developed from the traditional AHP. Despite the convenience of AHP in handling both quantitative and qualitative criteria of multi-criteria decision making problems based on decision maker's judgments, fuzziness and vagueness existing in many decision-making problems may contribute to the imprecise judgments of decision makers in conventional AHP approaches.

2. Numerical Illustration

Significant risk factors in an automobile supply chain that have been identified are:

- Supply Risk
    - Poor quality of raw materials
    - Raw parts scarcity
    - Decline in business relations with suppliers
- Process Risk
    - Product design risk
    - Lack of skilled operators
    - Machine breakdown
- Financial Risk
    - Cash flow disruptions
    - Low rate of return
    - High inventory cost
- Demand Risk
    - Shifting demand across time
    - Shifting demand across market
    - Shifting demand across product

Risk assessment of the above mentioned factors involves following steps:
Step 1: A hierarchical structure is created by defining multi-criteria decision problem. Each criterion has been divided into sub-criteria depending on the complexity of the decision problem.
Step 2: The questionnaire is sent out to around 200 industry experts and data is collected from about 46 industry experts for whom the reliability analysis using SPSS is carried out and this data was used for further analysis. The data was used for formulation of pair-wise comparison matrix and their consistency analysis is carried out.
Step 3 Chang's Extent analysis method is used to calculate fuzzy synthetic values.

A questionnaire, appendix, was prepared and sent to industry to collect responses. The responses were received using Google Forms, appendix. Of all the responses the mode values were used for further calculations and analysis, shown in the table 1 and Table 2.

Table .1 Mode values of different factors

Factors	Modes
Supply Risks	3
Process Risks	4
Financial Risks	2
Demand Risks	5
Poor quality of raw material	5
Raw parts scarcity	4
Decline in business Relations with suppliers	3
Product design risk	4
Lack of skilled Operators	3
Machine break-down	2
Cash flow disruptions	2
Low rate of return	3
Higher inventory cost	4
Shifting demand across time	5
Shifting demand across market	3
Shifting demand across products	4

2.1 Reliability Analysis

For reliability analysis we used IBM SPSS 20.0 software package. The responses obtained from the questionnaire were input in the software and the Cronbach's alpha value was calculated as 0.724, which is well within the acceptable range. This means the data is reliable for further analysis as shown in below Table 3 &4 and Table 5 & 6.

2.2 Pair-wise Matrix Construction

Based on those modal values for responses pair-wise comparison matrices were constructed. The values were taken based on the scale for pair wise comparison. The steps are illustrated below

- Pair-wise comparison was done starting with the criteria with highest rating, Demand Risk in this case.
- The Demand risk row was filled according to the scale.
- Then, second highest value was taken, Supply Risk and the row was filled according to the scale.
- And so on, till the matrix is completely filled.
- Similarly, other matrices were also completed.

Table.2 Pair-wise comparison matrix for primary criteria with respect to supply chain risk

	SR			PR			FR			DR		
SR	1	1	1	0.5	0.67	1	1	1.5	2	0.4	0.5	0.67
PR	1	1.5	2	1	1	1	1.5	2	2.5	0.5	0.67	1
FR	0.5	0.67	1	0.4	0.5	0.67	1	1	1	0.33	0.4	0.5
DR	1.5	2	2.5	1	1.5	2	2	2.5	3	1	1	1

Table.3 Pair-wise comparison matrix for sub-criteria with respect to supply risk

	Poor Quality of RM			Raw Parts Scarcity			Decline in Business Relation		
Poor Quality of RM	1	1	1	1	1.5	2	1.5	2	2.5
Raw Parts Scarcity	0.5	0.67	1	1	1	1	1	1.5	2
Decline in Business Relation	0.4	0.5	0.67	0.5	0.67	1	1	1	1

Table.4 Pair-wise comparison matrix for sub-criteria with respect to process risk

	Product Design risk			Lack of Skilled Operators			Machine Breakdown		
Product Design Risk	1	1	1	1	1.5	2	1.5	2	2.5
Lack of Skilled Operators	0.5	0.67	1	1	1	1	1	1.5	2
Machine Breakdown	0.4	0.5	0.67	0.5	0.67	1	1	1	1

Table.5 Pair-wise comparison matrix for sub-criteria with respect to financial risk

	Cash Flow Disruptions			Low Rate of Return			High Inventory Cost		
Cash Flow Disruptions	1	1	1	0.5	0.67	1	0.4	0.5	0.67
Low Rate of Return	0.5	0.67	1	1	1	1	1	1.5	2
High Inventory Cost	1.5	2	2.5	1	1.5	2	1	1	1

Table.6 Pair-wise comparison matrix for sub-criteria with respect to demand risk

	Shifting Demand Across Time			Shifting Demand Across Market			Shifting Demand Across Product		
Shifting Demand Across Time	1	1	1	1.5	2	2.5	1	1.5	2
Shifting Demand Across Market	0.4	0.5	0.67	1	1	1	0.5	0.67	1
Shifting Demand Across Product	0.5	0.67	1	1	1.5	2	1	1	1

2.3 Consistency Ratios

Consistency ratios are calculated to determine whether the responses are consistent throughout or not. Acceptable value is within **0.1** or **10%.** Consistency ratios were calculated for each matrix from I to V. Defuzzified matrix, A1, was constructed by using the formula, (a+4*b+c)/6; here a, b, c are the triangular fuzzy numbers. Then geometric means, GM were calculated across entire row and then their sum was also calculated as shown in below Table 7 &8 and Table 9.

Table.7 Geometric means in a defuzzified matrix for primary criteria

	Supply Risk	Process Risk	Financial Risk	Demand Risk	GM
Supply Risk	1	0.697	1.5	0.512	0.855
Process Risk	1.5	1	2	0.697	1.202
Financial Risk	0.697	0.512	1	0.405	0.616
Demand Risk	2	1.5	2.5	1	1.655
				SUM	4.329

Eigen Vector, A2 = GM/Sum
A3 = A1*A2.
A4 = A3/A2

Table.8 Value of A2, A3 and A4

Eigen vector / A2	A3	A4
0.198	0.800	4.040
0.278	1.125	4.047
0.142	0.577	4.063
0.382	1.550	4.058

$\lambda_{max,}$ mean of values of A4 = 4.052
CI= (λ_{max}—N) / (N—1), here N is size of matrix = 0.0173
CR = CI/RI, here RI is random index = 0.0173/0.9 = **0.0192**
CR for other matrices was also calculated on similar lines.

Table .9 Consistency ratios for sub-criteria

Matrix 2	Matrix 3	Matrix 4	Matrix 5
0.033	0.033	0.033	0.033

2.4 Extent Analysis

2.4.1 Fuzzy Synthetic values

Equation used to calculate Fuzzy Synthetic Values, Pair wise comparisons made are evaluated by using this methodology and explained in this section as shown in below Table 10 ,11 and Table 12, Table 13 & 14.
$\sum_{j=1}^{j=m} \mathbf{M}_{gi}^{j}$ and $\sum_{i=1}^{n} \sum_{j=1}^{m} \mathbf{M}_{gi}^{j}$ were calculated as shown below.

Table.10 Computation of fuzzy synthetic values

	SR			PR			FR			DR			SUM		
SR	1	1	1	0.5	0.67	1	1	1.5	2	0.4	0.5	0.67	2.9	3.67	4.67
PR	1	1.5	2	1	1	1	1.5	2	2.5	0.5	0.67	1	4	5.17	6.5
FR	0.5	0.67	1	0.4	0.5	0.67	1	1	1	0.33	0.4	0.5	2.23	2.57	3.17
DR	1.5	2	2.5	1	1.5	2	2	2.5	3	1	1	1	5.5	7	8.5
												Total	14.63	18.41	22.84

Fuzzy synthetic values, S, were obtained for the matrix.

$$\mathbf{S} = (\sum_{j=1}^{j=m} \mathbf{M}_{gi}^{j}) \otimes (\sum_{i=1}^{n} \sum_{j=1}^{m} \mathbf{M}_{gi}^{j})^{-1}$$

For primary criteria, Synthetic values are
S1 = (0.127, 0.199, 0.319)
S2 = (0.175, 0.281, 0.444)
S3 = (0.098, 0.140, 0.217)
S4 = (0.241, 0.380, 0.581)
Where,
S1 = Fuzzy synthetic values for the primary criteria
S2 = Fuzzy synthetic values for the sub-criteria with respect to supply risk
S3 = Fuzzy synthetic values for the sub-criteria with respect to process risk
S4 = Fuzzy synthetic values for the sub-criteria with respect to financial risk
S5 = Fuzzy synthetic values for the sub-criteria with respect to demand risk
Similarly, synthetic values for other matrices were also calculated.

Table.11 Fuzzy synthetic values for sub-criteria with respect to supply risk

Poor Quality of RM			Raw Parts Scarcity			Decline in Business Relation		
0.288	0.457	0.696	0.205	0.322	0.506	0.156	0.221	0.338

Table.12 Fuzzy synthetic values for sub-criteria with respect to process risk

Product Design risk			Lack of Skilled Operators			Machine Breakdown		
0.288	0.457	0.696	0.205	0.322	0.506	0.156	0.221	0.338

Table.13 Fuzzy synthetic values for sub-criteria with respect to financial risk

Product Design risk			Lack of Skilled Operators			Machine Breakdown		
0.288	0.457	0.696	0.205	0.322	0.506	0.156	0.221	0.338

Table.14 Fuzzy synthetic values for sub-criteria with respect to demand risk

Shifting Demand Across Time			Shifting Demand Across Market			Shifting Demand Across Product		
0.288	0.457	0.696	0.156	0.221	0.338	0.205	0.322	0.506

2.4.2 Degree of Possibility

For calculating degree of possibility of primary criteria
S1 = (0.127, 0.199, 0.319)
S2 = (0.175, 0.281, 0.444)
S3 = (0.098, 0.140, 0.217)
S4 = (0.241, 0.380, 0.581)

$$V(S_2 \geq S_1) = \mu(d) = \begin{cases} 1, & if\ m_2 \geq m_1 \\ 0, & if\ l_2 \geq u_2 \\ \dfrac{l_2 - u_2}{(m_2 - u_2) - (m_1 - u_1)} & \text{otherwise} \end{cases}$$

d′ (A1) = min (V ($Si \geq S$)) where, i ≠ k
V ($S1 \geq S2$) = 0.637
V ($S1 \geq S3$) = 1
V ($S1 \geq S4$) = 0.301
d′ (A1) = 0.301
V ($S2 \geq S1$) = 1
V ($S2 \geq S3$) = 1

$V(S2 \geq S4) = 0.672$

d′ (A2) = 0.672

$V(S3 \geq S1) = 0.604$

$V(S3 \geq S2) = 0.229$

$V(S3 \geq S4) = 0$

d′ (A3) = 0.000

$V(S4 \geq S1) = 1$

$V(S4 \geq S2) = 1$

$V(S4 \geq S3) = 1$

d′ (A4) = 1.000

2.4.3 Final Weights

Weight Vector, W1 = (0.301, 0.672, 0.000, 1.000) T
Normalization constant, c = 1.973
Normalized Weight Vector, W1 = (0.153, 0.340, 0.000, 0.507) T
Similarly, weights for sub-criteria were also calculated.
W2 = (0.558, 0.344, 0.098) T
W3 = (0.558, 0.344, 0.098) T
W4 = (0.098, 0.344, 0.558) T
W5 = (0.558, 0.098, 0.175) T
Where,
W1 = Weights for the primary criteria
W2 = Weights for the sub-criteria with respect to supply risk
W3 = Weights for the sub-criteria with respect to process risk
W4 = Weights for the sub-criteria with respect to financial risk
W5 = Weights for the sub-criteria with respect to demand risk

3. Results and Discussions

The FAHP model implemented shows the relative importance of various factors identified for Supply Chain Risk Assessment. The very low values of consistency ratios shows that the responses used were highly consistent and the data can be used for further analysis as show in below Fig 2 , Fig 3 and Fig 4 and Fig 5, Fig 6.
After calculating the final weights, it is easy to infer that Demand Risks have greater influence in decision-making in an Automobile Supply Chain. The Demand Risks are followed by Process Risks, which are followed by Supply Risks, and ultimately Financial Risks have the least influence on the decision-making.
The final results have been shown graphically in the following part:

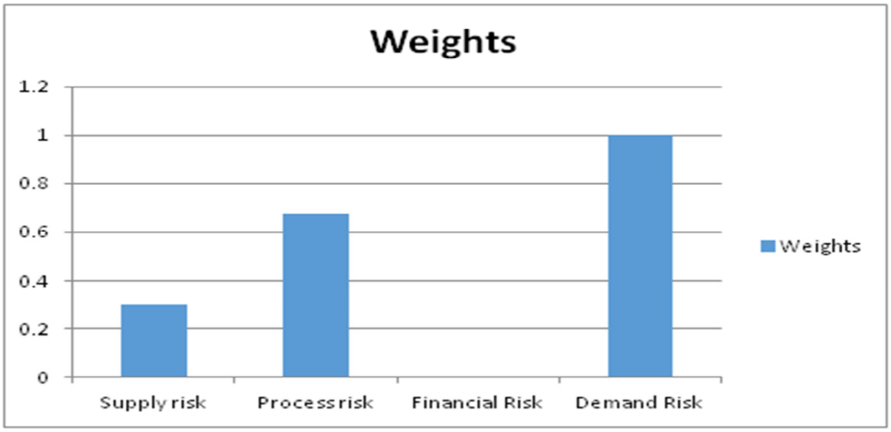

Fig. 2 Graph showing weight distribution for primary criteria with respect to supply chain risk Assessment

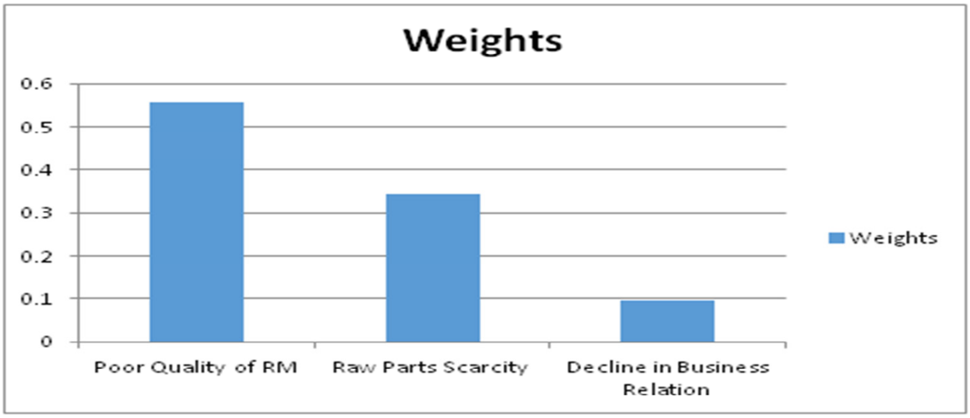

Fig. 3 Graph showing weight distribution for sub-criteria with respect to supply risk

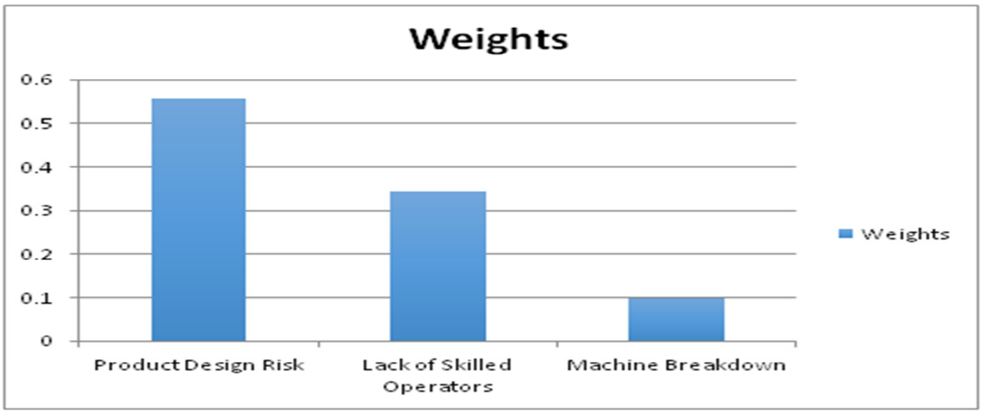

Fig.4 Graph showing weight distribution for sub-criteria with respect to process risk

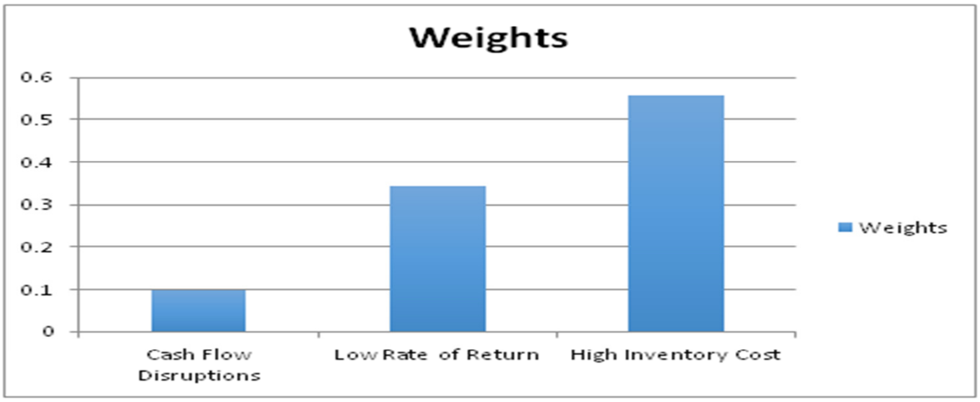

Fig. 5 Graph showing weight distribution for sub-criteria with respect to financial risk

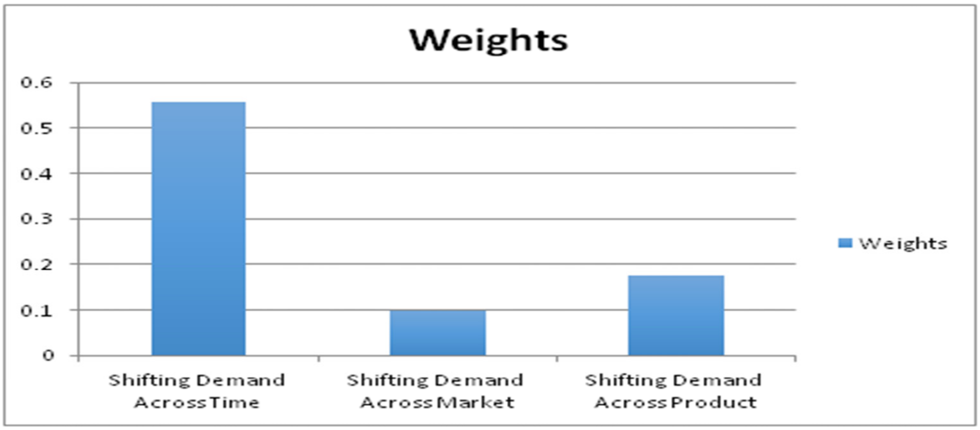

Fig.6 Graph showing weight distribution for sub-criteria with respect to demand risk

4. Conclusion

Supply Chain Risk is the potential occurrence of an incident or failure to seize opportunities in Supply chain in which its outcomes result in a financial loss for the firm.

We adopted FAHP decision making technique for risk assessment, for that first we identified four primary risk factors for our model and each of them had 3 sub criteria. A questionnaire was formulated using Google Forms and sent out to several automotive industries (Hero Motor Corp, Hyundai Motor, India, Tata Motors, Ford India, etc.) for responses. 46 responses were received and the reliability analysis was conducted using SPSS software for reliability analysis and the Cronbach's alpha value was found to be 0.724, which was within acceptable limit. Based on these responses, pair-wise comparison matrices were constructed and their consistency ratios were evaluated. The CR value were within acceptable range i.e. less than or equal to 0.10.

For data analysis Chang's Extent Algorithm was employed. First the synthetic values were calculated, based on those degree of possibility was evaluated. Finally the priority weights were obtained for the primary criteria and all the sub-criteria. This completed our decision-making model for Supply Chain Risk Assessment.

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