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SUPPLY CHAIN MANAGEMENT: RISK ASSESSMENT IN AUTOMOTIVE INDUSTRY USING FUZZY-AHP MODEL

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ABSTRACT

Recent advancement in technology has rapidly increased the activities in the automotive industry from the raw materials supply to the final sales of the finished product. This has led to the complexity in the supply chain management of the automotive industry and has increased the risk level in the industry. In this paper, a Fuzzy –AHP (Analytic Hierarchy Process) model has been used to perform risk assessment in automotive industry. Expert's opinion in the industry was consulted and some risk factors in automotive industry such as Policy Risk, Supply Risk, Demand Risk, Competitive Risk, Operational Risk, Regulatory Risk and Resources risk were identified and assessed using the proposed model. It was revealed through the assessment carried out that the resources risk will pose the highest level of risk in automobile industry. The Fuzzy model is adopted because of its ability to overcome vagueness. Review of existing work was carried out. The traditional AHP model and some other existing models were also explored.

Key words: Risk, Automotive industry, Fuzzy-AHP, Supply Chain, Assessment.

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1. INTRODUCTION

The most important issues in supply chain management are the identification and management of supply chain risk. This paper proposes a fuzzy analytical model for supply chain risk management (SCRM) in the automotive industry. A Fuzzy-AHP model for weighting the risk level and prioritize the alternatives of risk factors for assessment in SCRM. The inability of AHP to handle impression in the pair-wise comparison process has been improved in the FAHP to properly manage the decision-makers uncertainty. A case study of the automotive industry is applied to assess the results of the proposed model.

The role of supply chain management (SCM) in improving the automotive performance has been stated to be of great importance [1]. According to his work, the major components of the automotive industry are the supply management and physical distribution management. Tang et al.,(2007)[2] stated that the industry supply chain stretches from the producers of raw materials through to the assembly of the most sophisticated electronic and computing technologies.

According to (Cunlu and Peiqing, 2006), supply chain is a complex system which exchange different information, goods, material and money internally within the enterprise or externally with other companies [3]. In the automobile industry, supply chains can become increasingly complex with challenges that can reduce the profit as manufacturers design and build vehicles globally. Examples of such challenges may include long order-to-delivery lead times, unreliable production schedules, excess inventory across the supply chain and unstable supply of raw materials. Supply chain can also be influenced by undesirable factors, both from the outside environment and from the entities in the chain. All these constitute the risk factors that can negatively affect the output of an automotive industry hence a need for supply chain risk management.

Neiger et al., 2009[4] defines Supply Chain Risk Management (SCRM) as a process of identifying potential risks of entire supply chains, analyzing and determining characteristics and sources in order to manage the risks which can affect market, operational and financial performance.

The focus of this paper is to identify and assess both the internal and external supply chain risks factors that can affect the general performance of a large automotive industry. Consequently, the identified risk factors are ranked through an interview from the experts of heavy automotive industry manufacturer. According to Aditya Prakash (2017) [5] automotive companies trail top supply chains in implementing risk management practices due to the complex nature. In general, a supply risk management process consists of four major components: risk identification, risk assessment, risk management decisions and implementation and risk monitoring [6].

2. LITERATURE REVIEW

The need to manage the supply chains risks of business has become important due to the uncertainties in the world economy, business trends and advancement in information technology which has triggered the complexity of the supply chain [7]. According to Giannakis and Papadopoulou (2015), the extended supply chain has become vulnerable and businesses are now exposed to higher risks. They noted that typical supply chain risks include disruptions and delays, procurement related risks, logistics and transportation risks, supply chain relational risks, demand risk and infrastructure and systems risks [8].

Several methods have been applied in the past in the assessment and analysis of business risks. Rikhtehgar (2011) [9] developed a system for SCRM to reduce the influences of the SC risk factors. They applied both the fuzzy AHP and TOPSIS in order to allocate the weights to the risk factors and ranking members in order to identify the risks in the SC. Samvedi et al. (2013) classified the SC in four categories: supply risk, demand risk, process risk, and environmental risk and used fuzzy AHP and fuzzy TOPSIS methods to quantify the risk criterion [10].

Aqlan and Lam (2015) proposed an integrated framework for SCRM where the fuzzy inference system (FIS) was used to calculate the total risk score [11]. This was applied in a case study of the server manufacturing environment. A two-step fuzzy AHP approach for sustainable global supplier selection was also developed [12]. The system also considered the sustainability risks from sub-suppliers. Wu (2013) developed an integrated stochastic-fuzzy optimization approach for the SC outsourcing risk management using both random and fuzzy uncertainty [13]. An integrated fuzzy cognitive map and fuzzy soft set theory for supplier selection was developed by Xiao et al. (2012) [14]. This was applied for risk evaluation and they applied the ANP method.

A two-stage fuzzy AHP method to assess the risk of implementing green initiatives in the fashion SC was developed by Wang et al. (2012)[15]. A deterministic, stochastic, and fuzzy data envelopment analysis (DEA) approach in SCRM was proposed for vendor selection by Azadeh and Alem (2012) [16]. A fuzzy multi-objective programming to decide on the supplier selection using their risk factors was developed by Wu et al. (2010) [17]. A fuzzy SC network using the mean-risk optimization method under uncertainty situation in order to reduce the expected costs and risks was developed by Yang and Liu (2015) [18]. A mixed-integer non-linear mathematical model to represent uncertainties by using the fuzzy set theory in the SC was developed by Tabrizi and Razmi (2013) [19]. Yu and Goh (2014) developed a fuzzy multi-objective decision-making approach for supply chain visibility and the risks involved [20]. Ganguly and Guin (2013) used fuzzy AHP to assess the supply risk of a product category [21]. Xia and Chen (2011) presented a decision-making model for the SC risk system using ANP [22].

Jakhar and Barua (2014) proposed a decision-making model to measure, evaluate and improve the SC performance using structural equation modeling (SEM) and fuzzy AHP [23]. Chaudhuri et al (2013) proposed a group decision-making framework that used numeric and linguistic data to assess the risks in the SC in new product development process [24]. Radivojević and Gajović (2014) also developed a model for the SC risk using AHP and fuzzy AHP methods [25].

Wu et al. (2006) developed an analytic hierarchy process (AHP) based supplier risk assessment tool using the weights and the probability of each risk factor occurring for a supplier to compute an overall risk index .

2.1. Risk Factors for Automotive Industry

Daniela Marasova [27] identified the following risks in automotive industry: Supply risks, Operational risks, Demand risks, Security risks, Macro risks, Policy risks, Competitive risks, Resource risks and Other risks while assessing the supply chain in the industry.

Generally, the risks from automotive industry according to literature can be summarized into:

a) High Competition

b) Demand Volatility

c) Exchange Rate Risk

d) Raw Material Price

e) Supply Chain Disruptions

f) Regulatory Risk

g) Economic Instability

h) Access to Credit

i) Liquidity Shock

These have been categorized into three (3):

Business Risk: This is made up of High Competition and Demand Volatility

Economic Risk: for example Exchange Rate risk and Raw material Price

External Risk: such as Supply Chain Disruptions, disasters, Regulatory risk, Economic instability and government policy [27].

2.2. Fuzzy-AHP

Fuzzy AHP is widely used multi-criteria decision making models applied in various fields of research such as in Medical, Engineering, and Social Sciences. It is the advanced form of the original AHP model proposed by Satty. Here, fuzzy values have been used to replace the crisp values commonly used before due to the vagueness and the uncertainty nature of the business system. In this work, fuzzy-AHP has been adapted for the assessment of risk in the automobile industry. Fuzzy AHP has been a powerful tool for risk prediction since risks are subjective in nature [28]. Lotfi Zadeh [29] proposed an approach called fuzzy set theory to deal with vagueness.

3. METHODS AND TECHNIQUES

To effectively understand the risks in the supply chain of the automotive industry, the research will adopt the hybrid modeling technique; which is the combination of both quantitative and qualitative modeling techniques. Consultations were first made with the experts and their inputs were fed into the system. Also, in order to know, calculate and handle uncertainties and inaccurate risk data, the research adopts the fuzzy-based framework.

This framework will aid identification and effective analysis of risk associated with each actor across the supply chain, assess the risk the actors may face and to develop strategies to ease identified risk.

The first part of the system is the identification of risk variables. This will be followed by the assessment of the risk variables. This will be carried out through the risk inference system which is a fuzzy inference system for performing analysis. This will be done by evaluating the risk weight. All these will be evaluated in order to make necessary predictions.

3.1. Fuzzy Set

A fuzzy set as illustrated by [30]

$$\boldsymbol{A} = \boldsymbol{x}, \boldsymbol{\mu A}\ (\boldsymbol{x}))/\boldsymbol{x} \in \boldsymbol{X}\}\ ,$$

is a set of ordered pairs and **X** is a subset of the real numbers $\mathcal{R}$, where $\boldsymbol{\mu A}(\boldsymbol{x})$ is called the membership function which assigns to each object "$\boldsymbol{x}$" a grade of membership ranging from zero to one.

3.2. Triangular Fuzzy Numbers (TFN)

A triangular Fuzzy Number according to [30] is illustrated by a triplet (p’, q’, r’) where p’, q’and r’ represent lower, middle and upper values of support of a fuzzy number.

$$\mu_h(x) \models \begin{cases} \dfrac{x - p'}{q' - p'} (p' \leq x \leq q') \\ \dfrac{r' - x}{r' - q''}\ (q' \leq x \leq r') \\ 0, otherwise \end{cases}$$

$$\text{With } -\infty < p' \leq q' \leq r' \leq \infty$$

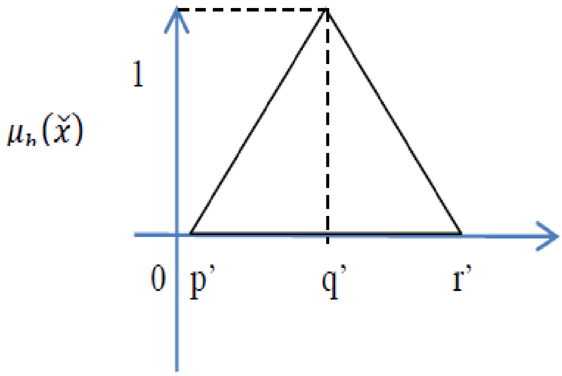

Figure 1 A figure showing the triangular fuzzy numbers with p’ and r’ as the lower and upper limits respectively [30].

3.3. Stages of Applying Fuzzy AHP for assessing risks in automobile industry

The following are the steps involved in using Fuzzy AHP for risk assessment:

Establishing hierarchy of risk set and establishing Criteria set based on expert opinion

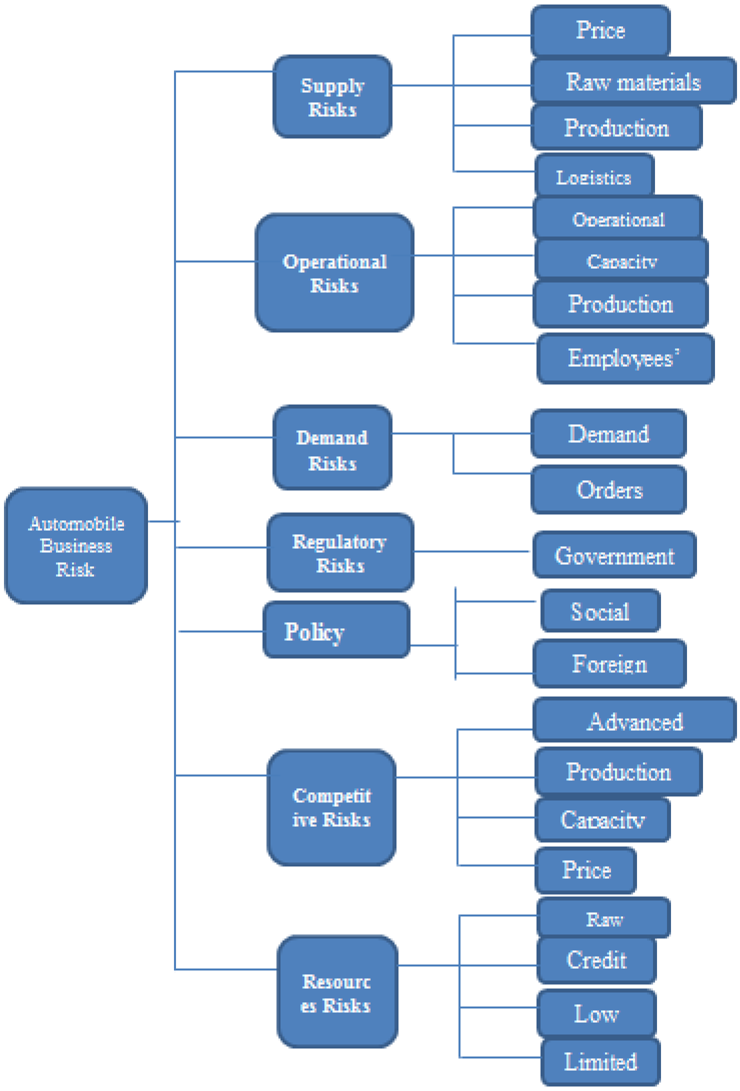

Figure 2 Figure showing the proposed structure of identified risks for automobile industry supply chain management

Determining evaluation matrix and the weights:

The experts make a pair-wise comparison of the decision criteria and give them relative scores as shown below.

Table 1 A table representing the risk level based on the assessment of experts

Assessment (Likelihood Of Occurrence)	Risk level	Description
Almost Certain	100	Expected to Occur
Very High	75	Likely to occur
High	50	50% chance of occurrence
Quite Likely	20	20% chance of occurrence
Moderate	10	10% chance of occurrence
Low	2	2% chance of occurrence
Very Low	1	1% chance of occurrence

Table 2 A table showing the Satty scale which has been modified using the Triangular Fuzzy Number [30]

Fuzzy Numerical Notation	Saaty Scale	Proposed Fuzzy Triangular Scale	Verbal interpretation of Scale
T1	1	(1, 1, 2)	Equal importance of both elements
T3	3	(2, 3, 4)	Moderate importance of one element over another
T5	5	(4, 5, 6)	Strong importance of one element over another
T7	7	(6, 7, 8)	Very strong importance of one element over another
T9	9	(8, 9, 9)	Extreme importance of one element over another
T2, T4, T6, T8	2, 4, 6, 8	(1, 2, 3); (3, 4, 5); (5, 6, 7); (7, 8, 9)	Intermediate trials

Proposed linguistic scale for fuzzy AH P adapted from [31]. This scale has been applied in Parkash's [32] fuzzy prioritization approach.

This can further be illustrated by the tables below showing the importance intensity. In this work, scale 9, 7, 5 are strong importance indicating high level of risks due to the likelihood of occurrence.

Table 3 A table showing the importance intensity of the triangular fuzzy number (TFN) adapted from [31]

Importance intensity	Triangular fuzzy scale	Importance intensity	Triangular fuzzy scale
1	(1, 1, 1)	1/1	(1/1, 1/1, 1/1)
2	(1, 2, 4)	1/2	(1/4, 1/2, 1/1)
3	(1, 3, 5)	1/3	(1/5, 1/3, 1/1)
5	(3, 5, 7)	1/5	(1/7, 1/5, 1/3)
7	(5, 7, 9)	1/7	(1/9, 1/7, 1/5)
9	(7, 9, 11)	1/9	(1/11, 1/9, 1/7)

The table below can then be deduced for the evaluation of matrix and weight using the appropriate techniques.

Table 4 A table showing the combination of risk nature, their corresponding assessment as carried out by expert, Satty scale, and Triangular fuzzy scale

Risk Nature	Assessment	Weighting	Importance intensity(Satty Scale)	Triangular fuzzy scale	Triangular fuzzy reciprocal
Supply Risk	Moderate	30	3	2, 3, 4	¼,1/3,1/2
Operational Risk	High	50	5	4,5,6	1/6,1/5,1/4
Demand Risk	Moderate	30	3	2,3,4	¼,1/3,1/4
Regulatory Risk	Low	10	1	1,1,1	1,1,1
Competitive Risk	Moderate	30	3	2,3,4	¼,1/3,1/2
Resources Risk	High	50	5	4,5,6	1/6,1/5,1/4
Policy Risk	Low	10	1	1,1,1	1,1,1

Final evaluation and assessment

From the above figures, we can have matrixes representing each of the risks in a pairwise comparison.

Table 5 The pairwise comparison matrix (input values) of the proposed risks weight of the automotive industry using the TFN

Risk	**R1(Policy Risk)**			**R2(Supply Risk)**			**R3(Demand Risk)**			**R4(Competitive Risk)**			**R5(Operational Risk)**			**R6(Regulatory Risk)**			**R7(Resources Risk)**		
R1	1.000	1.000	1.000	0.250	0.333	0.500	0.250	0.333	0.500	0.250	0.333	0.500	0.167	0.200	0.250	1.000	1.000	1.000	0.167	0.200	0.250
R2	2.000	3.000	4.000	1.000	1.000	1.000	0.250	0.333	0.500	1.000	1.000	1.000	0.167	0.200	0.250	2.000	3.000	4.000	0.250	0.333	0.500
R3	2.000	3.000	4.000	2.000	3.000	4.000	1.000	1.000	1.000	2.000	3.000	4.000	0.250	0.333	0.500	2.000	3.000	4.000	0.250	0.333	0.500
R4	2.000	3.000	4.000	1.000	1.000	1.000	0.250	0.333	0.500	1.000	1.000	1.000	0.250	0.333	0.500	2.000	3.000	4.000	0.167	0.200	0.250
R5	4.000	5.000	6.000	4.000	5.000	6.000	2.000	3.000	4.000	2.000	3.000	4.000	1.000	1.000	1.000	2.000	3.000	4.000	0.167	0.200	0.250
R6	1.000	1.000	1.000	0.250	0.333	0.500	0.250	0.333	0.500	0.250	0.333	0.500	0.250	0.333	0.500	1.000	1.000	1.000	0.250	0.333	0.500
R7	4.000	5.000	6.000	2.000	3.000	4.000	2.000	3.000	4.000	4.000	5.000	6.000	4.000	5.000	6.000	2.000	3.000	4.000	1.000	1.000	1.000

Where R1: Policy Risk R2: Supply Risk R3: Demand Risk R4: Competitive Risk R5: Operational Risk R6: Regulatory Risk R7: Resources risk

4. RESULTS AND DISCUSSIONS

After computations of the matrix in a pairwise manner, the following results in tabular form were got.

Table 6 The Geometric mean of fuzzy (TFN)

RISKS	**n*i***		
R1	0.331	0.394	0.500
R2	0.635	0.795	1.000
R3	1.000	1.369	1.811
R4	0.635	0.795	1.000
R5	1.548	2.015	2.479
R6	0.371	0.456	0.610
R7	2.438	3.192	3.904
Total	6.959	9.016	11.304
P (-1)	0.144	0.111	0.088
INCR	0.088	0.111	0.144

Table 7 Computed Fuzzy weight of each of the (TFN) risks

RISKS	***Wi***		
R1	0.029	0.044	0.072
R2	0.056	0.088	0.144
R3	0.088	0.152	0.261
R4	0.056	0.088	0.144
R5	0.136	0.224	0.357
R6	0.033	0.051	0.088
R7	0.215	0.354	0.562

Table 8 Averaged weight criterion (Mi) and Normalized weight criterion (Ni) of each of the risks number

RI	Mi	Ni	Rank
R1	0.048	0.045	6
R2	0.096	0.089	4
R3	0.167	0.155	3
R4	0.096	0.089	4
R5	0.239	0.221	2
R6	0.057	0.053	5
R7	0.377	0.349	1
TOTAL	1.080		

5. CONCLUSIONS

In this work fuzzy-AHP has been adapted for the assessment of risk in the automotive industry. Fuzzy values have been used to replace the crisp values commonly used before due to the vagueness and the uncertainty nature of the industry. This is an improvement in the traditional AHP. Normalized weight criterion (Ni) of 0.045,0.089,0.155,0.089,0.221,0.053 and 0.349 were got for R1,R2,R3,R4,R5,R6 and R7 respectively. The result shows R7 with the highest risk level followed by R5. The results truly validate the expert assessment of risks in the automotive industry.

In the future work, some other model can be applied on the same data set and the performance can be compared.

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