Ranking of factors by using IT2 Fuzzy FMEA for a trucking industry

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Abstract
Trucking industry plays a vital role in road freight transportation, because of its ease of accessibility. A systematic approach for factors identification and its ranking is required based on their criticality which affects the industry performance. Ranking of the factors has been performed by using interval type 2 fuzzy FMEA approach.

Keywords: Trucking industry, FMEA, IGMA, Risk Prioritization, mitigation action.

INTRODUCTION

The logistics sector plays a vital role in the economic growth of any country. A stable and efficient logistic system has the power to change the overall scenario of any country. For the world's second most populous country India, freight transportation is one of the most important components of the logistic system. Among different modes of freight movement, roads play a significant role in the development of any country. India has a huge geographical variation, with its agricultural land and manufacturing industries located mostly in the interior places, away from the main city. In such cases road transport as compared to rail, takes lions-share of the freights as they can reach each and every corner of the country. Today, the logistics industry of India has become one of the priority sectors in the overall growth of the country. For better stability in Indian road freight transportation, it needs a reliable and efficient trucking logistic system.

The logistic cost to the economy estimated for different countries are like USA 9 percent of the GDP, 11 percent for the Japan, 12percent for France and Korea respectively. However, for India, it's estimated around 12 to 15 percent, India Transport Report. It has been predicted that in the coming years, there will be a considerable growth in both manufacturing as well as the retail sector in the country (Deloitte, 2012). To sustain such a huge growth, India must have an efficient logistic system, but the trucking sector in India is highly fragmented, which prevents it from functioning in an efficient manner. According to a report by Deloitte, it has predicted that India will become one of the largest logistic markets in the world by 2024, (Delotte, 2014).

PROBLEM BACKGROUND

Trucks are the most suitable mode for freight movement, as it can cross both the geographical barriers and quantity barriers simultaneously. In India, there are over 40lakhs trucks and lorries as on 31st March, 2012 operating across the country as can be seen from Road transport year book (Road transport year book, 2013). This number is increasing at a fast rate.

The motivation to take up this problem came after analyzing several reports published on trucking industry by the government of India and other sources. Present situation of Indian industry is in wretched condition because of not getting attention for upgrading with respect to other dimensions in the dynamic nature of the current market. Most of the reports predicted that situation of the trucking industry is a major problem not only for India but also for the world. This area is still untouched for research in India. Initially, we need to identify the modes of failure of the present trucking industry. Identifying the failure modes is not sufficient , they also have to be prioritized on the basis of their severity.Prioritization of the failure modes will enable us to find out the major problems and accordingly work towards eradicating them.

REVIEW OF LITERATURE

FMEA has been proven as a great tool for risk assessment and prioritization process. In many cases it fails to deal with uncertainty, especially, in case of multi criteria decision making process by experts, where judgments are vague in nature. Substantial uncertainty and subjectivity are inherent in the risk assessment process. The traditional FMEA is unable to capture (a) Knowledge, attention and information processing capability of the experts (b) Vague assessment and grading criteria whose meaning, value varies considerably according to condition (c) fragmented experts' judgments as can be inferred from (Asan et al., 2015, Bozdag et al., 2015). It was concluded by Song that there is a lack of prior information and variation of opinion among different experts for the same risk factor in an uncertain environment during the decision making process.

IT type-2 FSs is having advantage of onsidering uncertainty in information, which makes it more accurate especially in MDCM as compare to T1 FS. There study shows that IT2 FSs is more accessible for the professionals, also required less time and effort to learn it (Mendel et al., 2009). For computing the overall priority represented by OLWA need to calculate lower and upper memberships function. For the computational process alpha cut decomposition method is used (Mendel and john, 2002) .

Supply chain vulnerability analysis and ranking was improved by FMEA for a Supply chain Reference operation model (SCOR) by (Liu, 2014) . The method employed for this purpose was the combination of Gray correlation and fuzzy set theory to overcome some disadvantages of traditional FMEA. FMEA analysis was considered as a diagnostic tool for understanding the causes and failure modes in a pharmaceutical reverse logistics supply chain process by Kumar and suggestions were made to track the logistics supply chain by using RFID (Kumar, 2009).

In the risk assessment process aggregation of data is an important step, which depends on the method of data collection. Several aggregation methods exist, however, interval mean aggregation (IMA) and interval geometric mean aggregation (IGMA) method are efficient and commonly used methods. Selection of the aggregation method plays an important role in multi criteria decision making (MCDM) process, where experts judgment is involved in the decision process. Wu and Adamcsek showed that when the number of experts involved in the decision

making process is large, IMA is more appropriate method and for a small number of experts IGMA gives more accurate results (Asan et al., 2015, Bozdag et al., 2015). Interval mean aggregation (IMA) has been used for aggregation of interval values in risk assessment and prioritization process (Bozdag et al., 2015) . Evaluation of risk factors in the supply chain for an automotive industry of Iran has been carried out for overall improvement of the performance of the industry (Bavarsad et al. , 2014).

Table 1- Severity, probability of occurrence and likelihood of detection scales, (Bozdag et al., 2015)

Rating	Severity	Probability of occurrence	Likelihood of detection
10	Hazardous without warning	Extremely high	Absolute uncertainty
9	Hazardous with warning	Very high	Very remote
8	Very high	Repeated failures	Remote
7	High	High	Very low
6	Moderate	Moderately high	Low
5	Low	Moderate	Moderate
4	Very low	Relatively low	Moderately high
3	Minor	Low	High
2	Very minor	Remote	Very high
1	Almost none	Nearly impossible	Almost certain

METHODOLOGY

Identification of risk factors

There are several factors like economic, political, and environmental factors which affect the trucking industry. In our study, we have identified 12 major failure modes, causes, and its effect in performance degeneration of the Indian trucking industry, as shown in table 2. Selection of these factors was carried out from the reports, other different sources, and field survey.

Data collection

After identifying failure modes, expert's opinion was collected for severity, likelihood of occurrence and detection in the interval form, as shown in table 3. The opinion of the experts has been collected in linguistic terms presented in Table.1.

Aggregation method

For further analysis, there is a need to aggregate the interval values; therefore, we are using (IGMA). Interval mean aggregation (IMA) has been used (Bozdag et al. 2015) for prioritization of risk factor, by using IT-2 Fuzzy Failure mode and effect analysis (FMEA).

Table 2- Potential failure modes causes and effect in Indian trucking industry

	Potential failure mode	Potential Effects of Failure	Potential Causes / Mechanisms of failure	Current Process Control (Prevention)
1	Shortage of drivers	Idle truck	Lack of career path	Family friendly schedule
2	Working environment (mentally or physically problems)	Shortage of drivers	Undue harassment by authorities/ poor quality of life	None National Highways Accident Relief Service Scheme (NHARSS),
3	Lack of career path	Shortage of drivers	No assurance and insurance	None
4	Operating cost	Sharp profit margin	High Competition,	None
5	Fuel cost	Sharp profit margin	Negative impact of price variation	None
6	Breakdowns cost and Maintenance cost	Delay/ accident	Operating condition of truck	Preventive and predictive maintenance
7	Under utilization	Empty traveling/ loss	Unused capacity/ intensive competition	None
8	Untrained / unskilled people	Accident	Fraud licensing	None
9	Intransit damage or loss/ theft	Loss it may be quality or quantity loss	Lack of caution / Irresponsibility during transportation	None
10	Octroi duty/ Taxation system	Delay and also encourage corruption	Waiting time is very high/ Multiple and differential inter and intra state level taxes	Non uniform taxation system

Computation of overall priority value

Before the valuation of overall priority values, the failure modes are synthesized over S, O and D by using ordered linguistics weighted average (OLWA). Ordered linguistic weighted average (OLWA) method proposed by Wu is a combination of ordered weighted average(OWA)

and linguistic weighted average (LWA) (Wu and Medle, 2007, Wu and Medle, 2008) . Calculation of weight vector has been carried out by using methods derived from Fuller and Majlende's, which depends on the situation parameters. Situation parameters provided by experts in the form of end point interval, between 0 to 1 (Fuller and majlender, 2001).

Table 3- Failure modes and experts judgment

Factors	Table: 2 failure modes and experts judgment								
	SEVERITY			OCCURRENCE			DETECTION		
	Expert 1	Expert 2	Expert 3	Expert 1	Expert 2	Expert 3	Expert 1	Expert 2	Expert 3
Shortage of drivers	(7, 10)	(8, 9)	(7, 10)	(6, 9)	(5, 8)	(7, 9)	(6, 8)	(5, 7)	(5, 8)
Working environment	(6, 8)	(7, 8)	(6, 7)	(7, 9)	(6, 10)	(8, 9)	(5, 7)	(6, 7)	(5, 8)
Lack of career path	(7, 8)	(6, 8)	(6, 9)	(5, 8)	(6, 9)	(7, 8)	(5, 6)	(6, 7)	(5, 6)
Operating cost	(7, 9)	(6, 9)	(7, 8)	(6, 9)	(7, 8)	(6, 8)	(5, 7)	(4, 6)	(6, 7)
Fuel cost	(7, 9)	(7, 10)	(8, 9)	(7, 8)	(6, 9)	(6, 8)	(9, 10)	(9, 10)	(9, 10)
Breakdowns and Maintenance cost	(7, 8)	(6, 8)	(7, 9)	(6, 8)	(5, 8)	(6, 9)	(5, 8)	(6, 8)	(5, 7)
Under utilization	(7, 9)	(6, 8)	(7, 9)	(7, 8)	(6, 7)	(7, 9)	(8, 9)	(7, 8)	(7, 9)
Untrained / unskilled/underage/overage drivers	(8, 9)	(7, 9)	(7, 8)	(7, 8)	(6, 9)	(6, 8)	(4, 6)	(5, 7)	(5, 6)
In transit damage or loss/ theft	(5, 7)	(4, 7)	(5, 7)	(4, 6)	(3, 5)	(3, 6)	(7, 9)	(8, 9)	(6, 8)
Octroi duty/ Taxation system	(6, 7)	(5, 8)	(6, 8)	(7, 9)	(6, 8)	(8, 9)	(7, 8)	(6, 8)	(5, 7)

Table 4- Mitigation action

S.No.	Strategy	Main objective
1.	Scheduled maintenance	To improve the service quality
2.	Dynamic assortment planning (Tang, 2006) [41]	To control the demand fluctuation
3.	Conciliation property	To manage and sustain their relationship in professionalism
4.	Compassable working environment	To attract professionals for the job
5.	Strategic policy to enter into business	To reduce fragmentation in the industry

6.	Regulatory impact	Regulatory changes can change better or worse of strategy
7.	Improvement of road design, signalling process	To minimize the road accident

Ranking overall priority

It is not possible to consider all the problems at a time. It is important to consider the problem in a proper manner according to the criticality of the problem. Finally, ranking of failure mode was completed by using the method developed (Asan et al., 2015), based on α-cuts. Table 4 shows that proposed mitigation strategy to controle the failure.

Overall ranking value, r_i

$$r_i = \frac{\int_0^1 G_i^M(\alpha)\left|G_{e_i}(\alpha)\right| d\alpha}{\int_0^1 \left|G_{e_i}(\alpha)\right| d\alpha} = \frac{\int_0^1 \left(\frac{g_{1_i}(\alpha)+g_{2_i}(\alpha)+g_{3_i}(\alpha)+g_{4_i}(\alpha)}{4}\right)\left(\frac{g_{3_i}(\alpha)+g_{4_i}(\alpha)}{2}-\frac{g_{1_i}(\alpha)+g_{2_i}(\alpha)}{2}\right) d\alpha}{\int_0^1 \left(\frac{g_{3_i}(\alpha)+g_{4_i}(\alpha)}{2}-\frac{g_{1_i}(\alpha)+g_{2_i}(\alpha)}{2}\right) d\alpha} \quad (1)$$

Table 5- Failure modes and expert's judgment

	Potential failure modes	Crisp Approach		IMA Approach		IGMA Approach	
		RPN	Rank	RPN	Rank	RPN	Rank
1	Shortage of drivers	405.1667	3	7.744781	3	7.713243	3
2	Working environment	362.0556	4	7.445065	4	7.40349	4
3	Lack of career path	306.5741	9	6.971059	9	6.934705	9
4	Untrained / unskilled/underage/overage drivers	322.6667	8	7.290591	6	7.279295	5
5	Operating cost	327.963	7	7.190588	7	7.167931	7
6	Fuel cost	580.5556	1	8.716348	1	8.701358	1
7	Breakdowns and Maintenance cost	341.25	6	7.151211	8	7.094036	8
8	Under utilization	449.7778	2	7.77911	2	7.756175	2
9	In transit damage or loss/ theft	205.625	10	6.56104	10	6.533221	10
10	Octroi duty/ Taxation system	356.8519	5	7.299422	5	7.27654	6

RESULTS AND DISCUSSION

Priority ranking of failure modes and comparison of result is provided in Table 5. Variation in fuel cost is most critical failure mode in all the methods, followed by problem of under utilization. A comparison has been made on the basis of the ranking values obtained using crisp approach, IMA and IGMA. Studies have shown the effectiveness of using IGMA. Validations of

the proposed model have been done by verifying the result with the experts. One of the major advantages of this approach is to provide flexibility to experts in the judgment process.

Our study is now able to answer some of the essential questions, viz; what are the potential modes of failure and which needs more attention for the betterment of the Indian Trucking industry. IT2 FSs in FMEA approach adopted because of its attribute to consider both inter and intra-personal uncertainty during taking opinion from different experts. Inevitably, there is also some limitations like here we have considered only 10 major failure mode for our study.

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