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Risk Prioritization in Perishable Food Product Chains Using Analytic Hierarchy Process

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***Abstract*—The fundamental objective of any organization is to remain competitive in their current market scenario and effectively manage their supply chains under risks and disruptions. Major risks related to food product supply chains are shortage of raw material, delivery delay and product reliability. Since the risks in the supply chains are inevitable the successful execution of any supply chain requires prioritizing and mitigating the risks based on their effect on the supply chain. The highly volatile and competitive nature of today's market causes a supply chain susceptible to vulnerability. Increasing occurrence of internal and external risks add further complexity in supply chain dealings. The management of risks or disruptions in the supply chain becomes more critical if the chain deals with products having perishable nature. Analytic Hierarchy Process (AHP) is a multi-criteria decision making (MCDM) tool for organizing and analyzing complex decisions. This article tried to explore the critical risks occurring in the supply chain of perishable products having daily demand. AHP is used to prioritize these risks based on critical criteria such as delivery delay, business interruption value. The prioritization of these risks helps to adopt proper mitigation strategies to nullify the undesired effect by these risks in the supply chain, so that a smooth and efficient product flow along the supply chain is ensured.**

Index Terms—AHP, Disruption, Risk, Supply chain, Vulnerability

I. Introduction

Supply chain is a network of facilities designed to procure, produce, and distribute goods to customers at right quantities, to the right locations and at the right time. The demand of the business environment and progression of emerging markets are leading to complex supply chain. So the chance of risk in this complex supply chain and its management are highly challenging. Risk is simply the probability of anything which is not desired to occur. The difficulty level of risk and its management depends on the complexity of the supply chain. Supply chain risk management (SCM) is one of the evolving or emerging field in the area of supply chain management. Risks and uncertainties are inevitable no matter how strong is the individual or institution in making decisions. These often come into the picture with some sort of unpleasant results with them. It is not only difficult to predict the outcomes of the events rather it is also difficult to avoid them in many real life situations. The uncertainties associated with demand, supply, cost, lead time, can result in severe economic losses, poor customer service, which finally leads to reputation loss of business. Supply chain coordination involves cooperation between firms sharing important information with each other in the process of developing, producing and distributing goods and services to end marketplaces.

Supply chain risk management (SCRM) is a systematic phased approach for identifying, assessing, prioritizing, mitigating, and monitoring potential disruptions in the supply chain in order to reduce the negative impact of these disruptions in supply chain operations [1]. Risk can occurs at any stage of supply chain. Identifying various risk in the supply chain is first task which is the most difficult one also. Risk identification can be done by different methods such as brain storming. The types of risks occurring in a supply chains depends upon the commodity which is dealt with in. However some types of risks are common in every supply chain like risks in supply, demand risks. The types of risks occurring in a supply chain depends on the product which the chain deals.

The complexity of risk management become at its peak if the supply chain deals with perishable products. The timely coordination of information is the vital fact in these types of supply chain. As the product perishes with time any delay in any one of the link in the supply chain will leads to failure of the chain. In this work the supply chain risk management of highly perishable food is dealt with.

II. Literature Review

Supply Chain Risk Management (SCRM) is one of the evolving sub-domain of supply chain management. Managing supply chain risk is a complex and challenging task because individual risks are interconnected and actions that mitigate one risk can end up making more complex another risk. SCRM is a field of high importance which aims to develop approaches which is a combination of both risk management and supply management. As each and every stage of supply chain have vital role in the satisfaction of customer, the risk management is one of the prominent topic in this area. There is no universal and widely accepted definition for SCRM. However according to [2] SCRM means the identification and management of risks for the supply chain through a coordinated approach amongst supply chain members, to reduce supply chain vulnerability as a whole. While [3] suggest SCRM is to collaborate with partners in a supply chain, apply risk management process tools to deal with risks and uncertainties caused by, or impacting on, logistics related activities or resources. According to [4] SCRM is the identification and evaluation of risks and consequent losses in global supply chain and implementation of

appropriate strategies through a coordinated approach among supply chain members with the objective of reducing one or more of the following ,losses, probability, speed of event, speed of losses, the time for detection of the events, frequency, or exposure for supply chain outcomes that, in turn, lead to close matching of actual cost savings and profitability with those desired. Supply chain risk management is the implementation of strategies to manage both every day and exceptional risk along the supply chain based on the continuous assessment with the objective of reducing vulnerability and ensuring continuity. SCRM try to reduce supply chain vulnerability through a coordinated approach involving all the stakeholders which identify and analyze the risk of failure points in the supply chain. Risk in the supply chain may ranges from unpredictable natural threats, reach across quality security, and product integrity. SCRM is essential for the smooth flow in the supply chain. Besides these SCRM has a strong influence on the stability of dynamic cooperation among the partners of the supply chain so it is important to the performance to all their operations. Therefore the objective of SCRM is to identify potential sources of risk and implement appropriate measures to avoid or restrict the vulnerability of the supply chain. This means controlling the factors that can cause negative effects on the normal functioning and improves its reliability.

A. Food Product Chain Risks

Food product supply chain involves a lot of areas and participants making them vulnerable to the influence of uncertain factors. In this environment, the probability of failure is high requiring contingency plans to avoid ruptures in the chain that harm the business. Supply chain risk can simply define as the event that disturb the smooth flow of goods and material in the supply chain. Several different sources of uncertainty have been recognized in Supply Chain Management literature. The vulnerability of supply chains to disruption risks is increased due to the globalization and business initiatives such as lean operation. According to [5] demand fluctuation is the major risk on demand side. Disruption in the chain may be due to different reasons such as physical damage at production facilities, natural disaster, strikes, labour disputes, capacity issues, inventory problems, incorrect forecast and delays. Supply chain risk can also be broadly categorized into disruption risk and operational risk [6]. Supply risk mainly includes risks like supply quality, supplier capacity, supply reliability, supplier insolvency. Process risk includes risks in quality, machine failure, and labour shortage product and process design. While the demand risk includes demand volatility, market changes, forecasting error, new product introduction. What makes risk management challenging is that today's climate is rapidly changing and the time frames of decision-making are getting smaller.

In the opinion of [7] quality problems of raw material is the major issue faced by supply side ,while [8] suggest incorrect ordering mechanism affect supply side quite badly. [9] Suggest that natural disaster terrorism and diseases also make hurdles in the smooth flow of supply chain. Food product supply chain risk in any country can be divided in to external risk and internal risk. Environmental risk can be further divided in to several categories such as natural disasters, political and instability risk, economic risk, legal risk, cultural risk, social risk, corruption, infrastructure and transportation risk. Although environmental risks are not related to supply chain they can significantly disrupt company operation, which in turn affects supply chain. Internal risks are related to a company's operation which includes warehouse risks, transportation, operational risks, port delays, ownership and control risk. Another classification of supply chain risk is external risk and internal risk. External risk are risks external to organizational while internal risks are risks occurring within the organizational Internal risks bring less consequence comparing to external risks. Internal risk mainly includes machine break down, production line down time. The control over the external risks for a firm is limited which mainly includes political instability, earthquakes, currency changes, etc... The only thing the firm can do to prevent these external risks are to make sure that the operation of the firm is strong or in other words firm should develop contingency plan in order to return to planned level.

B. Food Product Chain Risk Management

Managing supply chain efficiently to fulfil customer needs is challenging task. Various sources of uncertainty and complex interrelationship between different entities make the supply chain even harder to manage. Managing and controlling risk is an important aspect of effective supply chain management [10]. Research on supply chain risk management has received more attention in these days.

Ruptures and interruptions in the supply chain can cause large financial losses and which further affects the reputation of the firm. In order to control and mitigate negative effects caused by a variety of risks, a significant amount of work in the area of supply chain risk management has been undertaken in both academia and practitioner circles. Risk management includes the planning, organizing, implementing, and monitoring of activities intended to minimize risks to a tolerable level. The various links of supply chain are always under the chance of risk. Large manufacturing organization either succeed or fail depending on the effectiveness of their supply chain. In order to adapt quickly and effectively to the challenging environment, supply chain needs to be flexible and work in a more collaborative manner. Supply chain risk has emerged as a key challenge to supply chain management. According to [4] risk can be classified in to operational and disruption risk. Operational risks refer to the inherent uncertainties in supply, demand and price. Disruption risks denote the extreme risk events caused by natural and man-made disasters.

In the opinion of [2] SCRM is the identification and management of risk for a supply chain through a coordinated approach among supply members to reduce supply chain vulnerability as a whole. Supply chain risk management (SCRM) is a systematic phased approach for identifying, assessing, prioritizing, mitigating, and monitoring potential disruptions in the supply chain in order to reduce the negative impact of these disruptions in supply chain operations [1]. Management of supply chain risk through coordination or collaboration among supply chain partners as to ensure profitability and continuity [4]. Demand and supply risks have received much attention during 2005 to 2010. According to

[11]. The sharing of risk can be achieved by offering mutually beneficial risk sharing contracts which also raise the retailers order quantity to the expected value maximizing quantity.

[12] Proposed integrated selection of suppliers and scheduling of customer orders in presence of disruption risk and Bow Tie analysis and optimization techniques is proposed to quantify and mitigate supply chain risks. [13] Studied the moderating role of supply chain flexibility in risk mitigation. [14] Suggest some of the mitigation strategies which includes prevention or lowering of risk through understanding, controlling the impact of risk so that even if an adverse event occurs the impact is minimized, and mitigating risk by transferring it to other parties, diversification of products and risk pooling. [4] Suggest strategies like physical backup or redundancies, multi-location sourcing, pricing strategy [15] extends real option theory from a firm focus approach to the supply chain context and found evidence that several options operate differently for supply chain decisions than they do for firm decisions. [10] Studied redundancy mitigation strategy which is applied in insurance sector. [16] Studied supply chain risk in different ways such as dispersion of supply chain partners and its relation with the supply chain disruption risk and co-location of supply chain partners and its relation with the supply chain disruption. While [6] suggested two methods for managing disruption risk in supply chain one is to reduce the probability and other is to increase the capacity. The ultimate aim every supply chain risk management is to ensure supply chain continuity. As mentioned earlier SCRM mainly involves risk identification, risk assessment, mitigation strategy identification and implementation of the identified strategy. Effective supply chain risk management is essential to a successful business. It is also a competence and capability many enterprises have yet to develop. In some areas both problems and practices are well defined while in others problems are defined but practices are developing. In sum supply risk management is one of the evolving area in the supply chain management.

III. Methodology

The decision making methodology frame work adopted for the current work is shown below. A multi criteria decision making tool called AHP is used to prioritize the risk. The process starts with identifying potential or critical risks along the supply chain, followed by expert team formation .These experts were used to find the relative ranking of critical threats in the supply chain. While choosing the experts for panel formation utmost care should be taken, they should have deep knowledge in the area in which decision is going to take.

AHP is a multi-criteria decision making tool which makes use of experts knowledge and experience in making complex decision. AHP requires criteria based on which the alternatives can be compared. The Fig. 1, describes the methodology adopted for decision making. After giving individual rating to different risks in the supply chain. These judging is to be consolidated to make final decision. In the final step the individual prioritization of supply chain risks are used to finalize the criticality of each risk. The Fig. 2 describes the decision hierarchy adopted. The goal is to prioritize the supply chain risk based on the criteria such as business interruption value, delivery delay, cost of recovery and negative brand image.

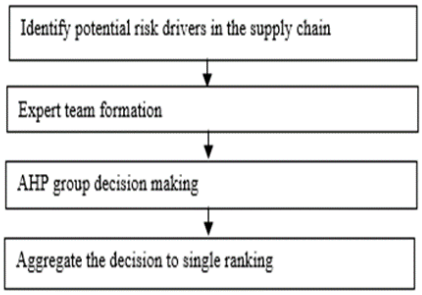

Fig. 1. Methodology of decision making

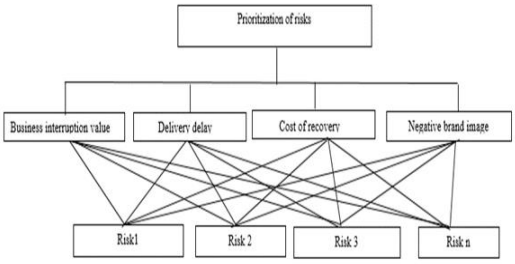

Fig. 2. Decision hierarchy

IV. Case Study

The case organization produces highly perishable food product. The firm has a well-established procurement and input section, production section and a competitive market section. Hence the expert team contain two expert from the procurement department, two from production and two from marketing department. A questionnaire survey was conducted to find the potential risks occurring along the supply chain. Formal interviews, informal interviews, observation study and check list were also used for this. The inputs from these findings were short listed.

A. Risks at the Inbound

The firm has well established Input and procurement department. Data is collected using different method such as observation study, check list, interviews. The critical risks short listed are as follows.

- Raw material shortage
- Delay in supply
- Lack of hygiene and scientific method
- Lack of leader ship quality

B. Risks at the Plant

The plant is subjected deep study and have discussion with the expert. Both formal and informal interviews conducted

with the operators, production managers, and other officials. The following important risks are short listed.

- Machine breakdown and power failure risk
- Shortage of water
- Human resource risk
- Improper handling risk
- Schedule of incoming material
- Delay in processing the material

C. *Risks at the Outbound*

A thorough study is conducted in the outbound of the supply chain. Interviews were conducted with marketing department officials and workers which include drivers and other agents. The following critical risks where short listed.

- Competition risk
- Spoilage risk
- Timely supply
- Lack of product reliability

The criteria identified were asked to compare each other to get the weightage of each one. Based on these criteria the experts give priority to each risk identified.

V. Results and Discussion

In this work the risks occurring along the supply chain of perishable food item is discussed. The weightage of different criteria is shown in the Table-1. It can be seen that risks occurring in the inbound of supply chain are more critical than outbound. The main reason behind this may be that the chain deals with the perishable food item.

TABLE I
Weight of Criteria

Criteria	Weight
Business interruption value	0.573
Delivery delay	0.272
Cost of recovery	0.057
Negative brand image	0.098

The overall priority of different risk is summarized in Table-2. In the inbound supply chain delay in supply and shortage of raw material are the top prioritized risk. The main reason for this may be the highly perishable nature of food product. The lack of hygiene and lack of leadership skill are the next prioritized risks. When considering the risk in the plant machine break down and risk due to improper handling are at the top. At the out bound of supply chain timely supply of the product should consider first followed by spoilage risk and product reliability. This proposed work is based on AHP a well-known based group decision making tool. The main advantage of AHP over other complex mathematical models are not only its simplicity and easiness to use but also it make use of experience and knowledge of experts which will reduce the chance of taking wrong decision.

TABLE II
Priority of Risks in the Supply Chain

Risks	BIV	DD	COR	NBI	Overall Priority(OP)
	0.573	0.272	0.057	0.098	
RMS	0.156	0.162	0.202	0.118	0.156530
DIS	0.212	0.168	0.147	0.054	0.180843
LSM	0.031	0.013	0.014	0.216	0.043265
LLQ	0.020	0.019	0.030	0.177	0.035684
MBR	0.183	0.069	0.131	0.018	0.132858
SOW	0.09	0.042	0.023	0.023	0.066559
HRR	0.045	0.061	0.028	0.073	0.051127
IHR	0.062	0.079	0.120	0.033	0.067088
SIM	0.071	0.043	0.062	0.023	0.058167
DIP	0.037	0.180	0.097	0.020	0.077650
CR	0.010	0.010	0.012	0.097	0.018640
SR	0.016	0.030	0.026	0.074	0.026062
TS	0.046	0.109	0.086	0.013	0.062182
LPR	0.022	0.016	0.023	0.063	0.024443

BIV - Business interpretation value
DD - Delivery Delay
COR - Cost of recovery
NBI - Negative of recovery
SIM - Schedule of Incoming Material
OP – Overall Priority
RMS – Raw Material Storage
LPR – Lack of product reliability
LSM – Lack of hygienic and scientific method
LLQ – Lack of leadership quality
MBR – Machine breakdown and power failure risk
SOW – Shortage of water
HRR – Human resource risk
IHR – Improper handling risk
DIP – Delay in processing
CR – Competition risk
SR – Spoilage risk
TS – Timely Supply
DIS – Delay in supply

VI. Conclusion

Recently, supply chain risks and its management got more attention in industries and academics. Many papers have dealt with risk management issues in supply chains. As perishable product supply chain becomes more competitive the chance of vulnerability and disruptions increases. Both quantity and quality of the dealing product should be cared simultaneously in perishable product supply chain management.

This work tried to find the critical risks such as inbound risk, risks in plant and out bound risks in the highly perishable product chain using AHP. The proposed frame work consolidates expert opinion who were professionally qualified and well experienced in the perishable product supply chain management. Based on critical criteria such as business interruption value, delivery delay, cost of recovery and negative brand image the risks are well prioritized in tune with realistic scenario conditions. Furthermore the proposed method is suitable for any kind of perishable food product chain in real world.

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