Application Fuzzy DEMATEL to Develop a Cause and Effect Model of Risk in Supply Chain

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***Abstract*—Global and outsourcing environment that enterpriser how to management supply chain has become one of the important issues. Enterprises apply collaborative commerce with partners that relative risk will affect each others. The study use fuzzy DEMATEL method and integrate SCOR model to find cause and effect risk in the supply chain. Then, we interview 7 experts to verify the result. The result of study can help enterprise to forecast and risk management which risk will occurrence together in the supply chain.**

Keywords-Supply chain management;Risk management;SCOR; Fuzzy DEMATEL

I. INTRODUCTION

Supply chain management is important for improving competitive in an era of international economics. Risk exists at various levels, inside the company and at the network level in the supply chain. Risk evaluation is inherently subjective, because each analyst has his or her own concept of what constitutes a risk and of what is the nature of the upstream and downstream relationships [7].

However, few methods and studies the relationship between risks in the supply chain. The advantage of the DEMATEL method is the capability of revealing the relationship between these risks which affect other risks in supply chain. This paper main objective is (i) through literature review to define SCM risk factors; (ii) use fuzzy DEMATEL method to demonstrate the association between the risk factors; (iii) propose suggestions to industrial and academic reference.

II. LITERATURE REVIEW

A. *Supply Chain Managemen t*

Supply chain management (SCM) is defined as a set of methods used to interconnect suppliers, manufactures, warehouses and clients so that the merchandise is produced and distributed at the right quantities, to the right place at the right time with the objective of minimizing global system costs and maximizing the customer service levels [1][12][14][16]. Lamber et al.(1998)[6]proposed that SCM is the integration of key business processes from end use through original suppliers that provides products, services, and information that add value for customers and other stakeholders.

B. *SCOR Model*

SCOR model is intended to be an industrial standard. It contains a standard description of management processes, a framework of relationships among the standard processes, standard metrics to measure process performance, management practices that produce best-in-class performance, and a standard alignment to software features and functionality [17]. The SCOR model is originally founded on five distinct management processes, namely, Plan, Source, Make, Deliver and Return which are called Level 1 processes as Figure 1.

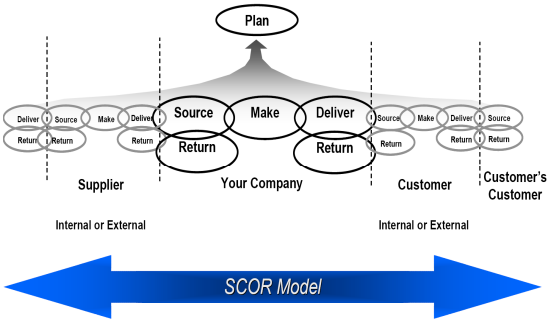

Figure 1. SCOR process

SCOR model activities included the customers to supplier process in the supply chain. The study will use the SCOR model level 1 to class SCM risk source.

C. *Risk Management*

Harland et al. (2003)[5]proposed that risk can be broadly defined as a chance of danger, damage, loss injury or any other undesired consequences. A risk formula to access the probability of loss '*P*' ($loss_n$) and the significance of the loss '*l*' ($loss_n$) for an event *n*:

$$Risk_n = P(loss_n) * l(loss_n)$$

Risk sometimes is interpreted as unreliable and uncertain resources creating supply chain interruption, whereas uncertainty can be explained as matching risk between supply and demand in supply chain processes.

D. *Risk Management process*

Hallikas et al.(2004)[9]proposed that risk management process of an enterprise consist of (1)Risk identification

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(2)Risk assessment (3)Decision and implementation of risk management actions (4) Risk monitoring. Risk management process includes risk identification, risk assessment, risk treatment, incident handing, contingency planning and risk monitoring as Figure 2 [3]. We focus on risk identification and risk assessment stages.

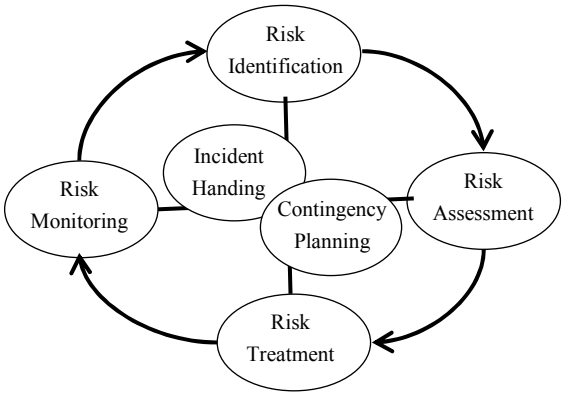

Figure 2. Risk Management process

E. SCM Risks

Environment and organizational uncertainties are risk sources to the various links in the supply chain and network-related uncertainties are risk sources of the various links [1]. Supply risk probability of an accident associated with inbound supply from individual supplier failures or the supply market occurring, in which its outcomes result in the inability of the purchasing firm to meet customer demand or cause threats to customer life and safety [8].The study used SCOR level 1 to classify supply chain risk. But, return process deals with managing reverse flow of material and information related to defective that including all stages. And the phenomenon is plan, source, make, delivery stages appear problems that led to return. We further categorize perspectives of risk events into the stages of plane, source, make and deliver. The results are summarized in TABLE I .

TABLE I SUPPLY CHAIN RISK FACTORS

SCOR Level 1	No.	Risk Factors	Authors
Plan	P1	Difficulty in accurate forecasting of demand	[13][17][18][20]
	P2	Demand and supply uncertainty	[17]
	P3	Managers decision-making error	[15]
	P4	Select wrong partners	[8][20]
Source	S1	Single sourcing risk	[8]
	S2	Supply product quality	[8][20]
	S3	Inability to meet quantity demand	[8][20]
	S4	Delays in material deliveries	[10]
	S5	Price/cost increase	[8][18][20]
	S6	Supply capacity	[8][18][20]
Make	M1	Order information errors	[20]
	M2	Manufacturing poor quality products	[13][20]
	M3	Product development problems	[8][10]
	M4	Operational disruption(Natural disasters/terrorists)	[20]
Deliver	D1	Delivery failures	[8][18][20]
	D2	Unable to meet customer specification	[8]
	D3	Highly dependent on one customer	[10][18]
	D4	Failure of new products in the marketplace	[10]

III. RESEARCH METHOD

The study purpose is to develop a cause and effect model of risk in the supply chain. DEMATEL is an extended method for building and analyzing a structural model for analyzing the influence relation among complex criteria. However, making decisions is very difficult in fuzzy environment to segment complex factors [4]. The study will use fuzzy DEMATEL method to obtain a more accurate analysis.

A. DEMATEL method

DEMATEL method is based on digraphs, which separate involved factors into cause group and effect group. Directed graphs, known as digraphs, are more useful than directionless graphs because digraphs demonstrate the directed relationships of sub-systems. DEMATEL method involves a seven-step algorithm as follows [4]:

1) Define element: A system containsa set of elements K = { k_1; k_2; . . . ; k_n}, the element that this study use literature review to find 18 risk in the supply chain.

2) Pair-wise comparison scale: the pair-wise comparison scale may bedesignated into four levels, where scores of 1, 2, 3, and 4 represent"very low influence", "low influence", "high influence", and"very high influence" respectively.

3) Direct-relation matrix: Thedirect-relation matrixT is a n * n matrix obtained by pair-wise comparisons interms of influences and directions between criteria, in which $T_{ij}$is denoted as the degree to which the criterion *i* affects the criterion*j*,*i.e.*, $T = [T_{ij}]_{n*n}$.

4) Normalized direct-relation matrix: Nnormalized direct-relation matrix S,i.e., $S = [S_{ij}]n \times n$ and $0 \leq S_{ij} \leq 1$ can be obtained through the formulas (1) and (2), in which all principal diagonal elements are equal tozero

$$K = \frac{1}{max_{1 \leq n} \sum_{j=1}^{n} a_{ij}} \quad (1)$$

$$S = K \times T \quad (2)$$

5) Calculate direct-relation matrix: A total-relation matrix M can be acquired by using the formula (3),in which the I is denoted as the identity matrix.

$$M = X(I\text{-}X)^{-1} \quad (3)$$

6) Calculate prominence and relation: The sum of rows and the sum of columns are separatelydenoted as D and R within the total-relation matrix M throughthe formulas (4)-(6):

$$M = m_{ij},\ i,j = 1,2,\ldots,n \quad (4)$$

$$D = \sum_{j=1}^{n} m_{ij} \quad (5)$$

$$R = \sum_{i=1}^{n} m_{ij} \quad (6)$$

7) Draw causal diagram: a causal and effect graph can be acquired bymapping the dataset of (**D+R**, **D-R**), where the

horizontal axis(**D+R**) is made by adding D to R, and the vertical axis (**D-R**) ismade by subtracting R from D.

B. Fuzzy theory

Fuzzy theory introduces the concept of membership function in order to deal with different linguistic variables [11]. Fuzzy logic enables us to emulate the human reasoning process and make decisions based on vague or imprecise data. In fuzzy set theory, elements of a set are allowed to have membership values between 0~1. A fuzzy set is usually shown by membership functions which can be of any shape by which the membership values can be computed for any element [2].The study use triangular fuzzy number. A triangular fuzzy number $\tilde{A}$ is shown as a triplet (*l*,*m*,*r*) as Figure 3.

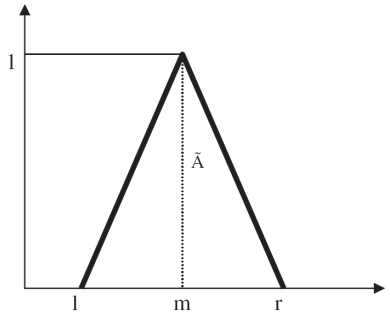

Figure 3. A triangular fuzzy number $\tilde{A}$

Then, we use gravity method to defuzzy and integrate crisp value (7).

$$S_i = \frac{a_i + b_i + c_i}{3} \quad (7)$$

IV. DATA ANALYSIS

A. Fuzzy DEMATEL

This study uses an expert interview method. We interview 7 experts in the supply chain field. The evaluation criteria symbols in the study as follow (P1)~(P4) in plan stage; (S1)~(S6) in source stage; (M1)~(M4) in make stage; (D1)~(D4) in deliver stage. The Fuzzy DEMATEL method steps as following [4]:

1) Set up Direct-Relation Matrix Z: First step sets up a direct-relation matrix Z form the data collected as *TABLE II*.

TABLE II *Direct-relation matrix Z*

	P1	P2	P3	P4
P1	0	3	3	2
P2	1	0	3	0
P3	3	0	0	3
P4	2	3	0	0

2) Design the fuzzy linguistic variables as TABLE III. The study transforms direct-relation matrix Z into triangular fuzzy numbers as *TABLE IV*

TABLE III Fuzzy linguistic scale

Linguistic terms	Influence score	Triangular fuzzy numbers
No influence (No)	0	(0, 0, 0.25)
Very low influence (VL)	1	(0, 0.25, 0.50)
Low influence (L)	2	(0.25, 0.50, 0.75)
High influence (H)	3	(0.50, 0.75, 1.00)
Very high influence (VH)	4	(0.75, 1.00, 1.00)

TABLE IV *Triangular fuzzy numbers*

	P1			P2			P3			P4		
P1	0.0	0.0	0.0	0.5	0.75	1.0	0.5	0.75	1.0	0.25	0.5	0.75
P2	0.0	0.25	0.50	0.0	0.0	0.0	0.5	0.75	1.0	0.0	0.0	0.25
P3	0.5	0.75	1.00	0.0	0.0	0.25	0.0	0.0	0.0	0.5	0.75	1.0
P4	0.25	0.5	0.75	0.5	0.75	1.0	0.0	0.0	0.25	0.0	0.0	0.0

3) Transform triangular fuzzy numbers into the initial direct-relation matrix as TABLE V.

TABLE V Direct-relation matrix F

	P1	P2	P3	P4
P1	0.000	0.750	0.750	0.500
P2	0.250	0.000	0.750	0.083
P3	0.750	0.083	0.000	0.750
P4	0.500	0.750	0.083	0.000

4) Obtain average value: The study obtain average valueof matrixes F from the total amount of all direct-relation matrixes F divided by 7.

5) Set up the gereralized direct-relation Sthrough formula(1) in which all elements are between 1 to 0 asTABLE VI.

TABLE VI Direct-relation matrix S

	P1	P2	P3	P4
P1	0.000	0.679	0.571	0.310
P2	0.417	0.000	0.500	0.190
P3	0.381	0.190	0.000	0.643
P4	0.226	0.405	0.274	0.000

6) Set up the total-relation M. The study use Eq. (2)(3) to acquire total-relationM as*TABLE VII*

TABLE VII *Total-relation M*

	P1	P2	P3	P4
P1	0.733	1.148	1.173	0.966
P2	0.778	0.647	0.945	0.744
P3	0.760	0.783	0.696	0.945
P4	0.587	0.733	0.714	0.500

7) Obtain the sum of rows and columns.We use Eq.(4)(5)(6) to sum of rows and the sum of columns are separatelydenoted as D and R within the total-relation matrix M.

8) Set up degrees of central role and relation.We calculate direct/indirect matrix M value. The results are showed in *TABLE VIII* and

9) TABLE IX.

TABLE VIII *direct/indirect matrix M*

	P1	P2	P3	P4	S1	S2	S3	S4	S5	S6
D	4.020	3.114	3.183	2.534	3.376	2.65	2.206	2.529	2.291	3.576
R	2.858	2.578	3.527	3.155	1.977	2.784	3.482	2.140	2.957	3.291
D+R	6.878	5.693	6.710	5.689	5.352	5.436	5.688	4.669	5.248	6.867
D-R	1.162	0.536	-0.344	-0.621	1.399	-0.131	-1.275	0.388	-0.667	0.285

TABLE IX *direct/indirect matrix M*

	M1	M2	M3	M4	D1	D2	D3	D4
D	3.274	3.553	2.266	2.681	4.229	4.573	3.909	3.137
R	1.515	2.872	3.345	4.043	2.527	3.770	3.907	5.644
D+R	4.789	6.425	5.611	6.724	6.757	8.344	7.816	8.780
D-R	1.760	0.681	-1.079	-1.363	1.702	0.803	0.002	-2.507

10) Set up the causal diagram. The horizontal axis (**D+R**) which the degree of central role. The vertical axis (**D-R**) which is degree of relation.The result show as Figure 4~Figure 6.

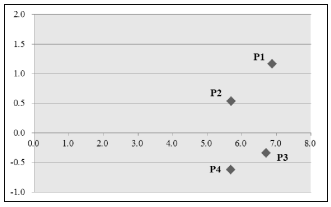

Figure 4Causal diagram in Plan

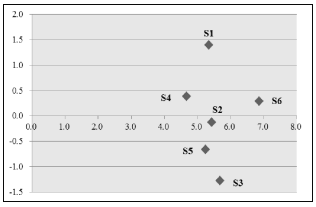

Figure 5 Causal diagram in Source

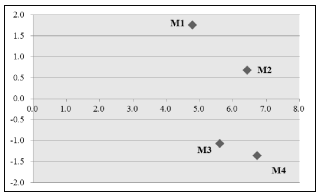

Figure 6 Causal diagram in Make

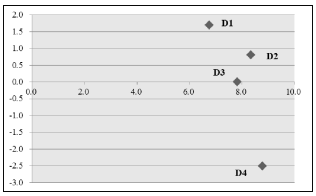

Figure 7 Causal diagram in Deliver

B. Analyzing illustrate

DEMATEL method indicates that (**D+R**) larger the factors are more important. If (**D-R**) positive larger the factor will affect other factors, but the (**D-R**) negative larger means the factors are affected. Research results show the most important criteria are the value greater than mean. Difficulty in accurate forecasting of demand (**P1**), Managers decision-making error (**P3**) is most important in the Plan stage. Inability to meet quantity demand (**S3**) and Supply capacity (**S6**) is most important in the Source stage. Manufacturing poor quality products (**M2**) and Operational disruption (**M4**) is most important in the Make stage. Deliver failures (**D1**), Unable to meet customer specification (**D2**) and Failure of new products in the marketplace (**D4**) is most important in the Deliver stage. Final, we draw cause and effect model of risk in the supply chain diagram and integrate SCOR process. The results show as Figure 8.

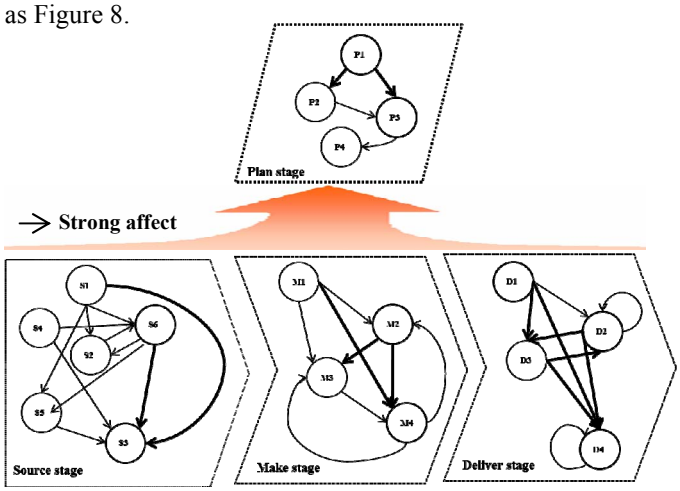

Figure 8. *Cause and Effect Model of Risk in Supply Chain*

V. CONCLUSION AND FUTURE RESEARCH

The study use fuzzy DEMATEL method to find cause and effect risk in the supply chain. The result of study can help enterprise to forecast which risk will occurrence together in the supply chain. Future study will use case to verify the model and consider the correlation between the construct factors.

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