Analysis of Vulnerability in Multinational Retailing Delivery Service System: A Case Study of FamilyMart and Circle K

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Abstract: Supply chain management has been widely studied both academically and in practice. The logistics process is complicated and faces many risks. However, there are few studies about the performance of multinational retailing delivery service systems. Vulnerability is a new concept in risk analysis. If managers understood the most vulnerable parts of business, they could take action and allocate resources to avoid risk. This study develops an evaluation model and discusses the vulnerability of a multinational retailing delivery system via the fuzzy cognitive map and sensitivity model. From a survey, we establish an evaluation model to analyze and describe the vulnerability and resilience of the multinational retailing delivery system using various research methods. The results obtained in this study can be used to help managers formulate strategies and reduce risks proactively.

Keywords: Vulnerability, Multinational Retailing Delivery Service, Fuzzy Cognitive Maps, Convenience Store

1. INTRODUCTION

The Internet represents an extensive and a growing market, and the development of e-commerce is an efficient business model that enables new relationships to be created between consumers and suppliers. In order to send goods or products to customers quickly and safely, strong support from an efficient logistics system is necessary. In Taiwan, many e-tailers (retailers who sell goods via electronic transactions on the Internet) have formed close partnerships with widespread convenience stores in the area of retailing delivery (RD) systems. These are based on resolving delivery problems, so that consumers can order the goods on websites and pick up their ordered goods at a convenience store, based on their scheduling preferences. In the logistics system of electronic commerce, the major difference between Taiwan and other countries is the RD system. In contrast to home delivery, people using retail delivery do not need to wait for their products at home, and thus have more flexibility to select the time and store that are most convenient. To date, convenience stores in Taiwan have integrated the delivery service in combination with an online store in Hong Kong to develop a new retail delivery model, the Multinational Retailing Delivery System. Thus, e-commerce between Taiwan and Hong Kong will become closer and inseparable. Because of the advantages inherent in the concept of retailing delivery, the delivery mechanism will play an important role in the delivery system between Taiwan and Hong Kong.

Taiwan and Hong Kong have a high density of convenience stores. Also, most stores in

* Corresponding author.
Taiwan and Hong Kong provide 24-hour service. According to this operational model, FamilyMart (Taiwan) and CircleK (Hong Kong) have already developed a multinational retailing delivery model. More and more famous e-commerce systems, such as KingStone, Books, and SanMing, cooperate with convenience stores to provide multinational retail delivery services for their customers in Hong Kong. Customers can buy books through Taiwan’s online bookstore service, and can pick up their books conveniently in a Hong Kong convenience store (CircleK).

Vulnerability is a new concept in supply chain risk management. In recent years, a growing number of studies in different fields have examined this issue, particularly because of the recent series of catastrophes and hazards that impacted the global economy causing large losses. Supply chain risk management (SCRM) is no exception. Although a substantial number of studies in supply chain vulnerability have been carried out to date, most of them employed qualitative analysis. In addition, relatively little research has been conducted on a specific system or company. While the multinational retailing delivery model has been remarkably successful, it is also complicated to implement with many inherent risks. For the past few years, supply chain management has been widely studied both academically and in practice. However, there are few studies about the risk of collaborative transportation management for the FamilyMart multinational delivery service. Risk management is regarded as an important issue in supply chain management. The objective of this study is to develop an evaluation model and discuss the risk of logistic delivery systems using the fuzzy cognitive map (FCM) and sensitivity model (SM). From our survey, we can establish an evaluation model to analyze and describe the vulnerability and resilience of the delivery system using different kinds of research methods. The results obtained in this study can be used to help managers formulate strategies and reduce risks proactively.

2. LITERATURE REVIEW

The vulnerability concept was first applied in the natural sciences. Scholars of natural hazards explored the relationship between vulnerability and environmental change. Turner et al. (2003) believe that a complete vulnerability assessment must include three basic elements: exposure, sensitivity, and adaptive capacity. Exposure refers to the risk of experiencing catastrophic events, and adaptive capacity includes the ability to withstand shocks, to continue operations, and to recover from attacks (Cutter, Boruff and Shirley, 2003; Tierney and Bruneau, 2007). Adger (2004) divide vulnerability into two attributes: biophysical vulnerability and social vulnerability. The former expresses the occurrence of weather-related events and the possibility of attacks; the field of exploration includes the degree of damage produced by weather, events, or hazards to the system. The focus of biophysical vulnerability lies in exploring the situations of human exposure in hazardous regions. Social vulnerability refers to people’s inability to handle stress or changing social and economic factors.

Supply chain risk management is an important issue in today’s business operations. However, nonlinear and uncertain risks can potentially increase difficulties in managers’ predictions and supply chain risk management. In recent years, along with the growing popularity of the Internet, the worldwide trading volume and frequency have gradually increased and led to the formation of the concept of a globalized supply chain. Supply chain disruption can have a great impact on corporate financial performance, so it is widely accepted that supply chain risk management (SCRM) is necessary in today’s business networks (Wagner and Neshat, 2009). Supply chain vulnerability forms the conceptual framework of supply chain risk management. A supply chain is exposed not only to risks that
come from the external environment, but also risks caused by suboptimal interactions between organizations within the network. That is, while supply chain disruption is a situation that leads to the occurrence of risk, it is not the only determinant of the final result. The susceptibility of the supply chain to harm in this situation seems relevant. This leads to the concept of supply chain vulnerability (Jüttner et al., 2003; Wagner and Bode, 2006).

In past decades, the numbers of studies about supply chain vulnerability have increased rapidly, in response to nature and man-made disasters increasing noticeably in number and intensity. Wagner and Neshat (2009) interpreted the relationship between supply chain disruption and supply chain vulnerability. According to them, supply chain vulnerability cannot be observed directly. There may be drivers or antecedents that lead to this concept. As the figure shows, supply chain vulnerability is generally considered to come from three directions: demand side, supply side, and supply chain structure (Wagner, Bode and Koziol, 2009; Wagner and Neshat, 2009). The demand side structure is vulnerable to the random demands of customers (which is the main cause of the vulnerability), the product and its characteristics, and the distribution and transportation operations required for serving the customer; the supply side is vulnerable to the supplier portfolio and the supplier network; and the supply chain structure is vulnerable to the disintegration of supply chains and the globalization of value-adding activities.

As shown in Table 1, Christopher and Peck (2004) define supply chain vulnerability as “an exposure to serious disturbance”. Tierney and Bruneau (2007) describe vulnerability as “a susceptibility or predisposition to loss because of existing organizational or functional practices or conditions” in their study of the maritime supply chain. Wagner and Bode (2006) state that “supply chain vulnerability is a function of certain supply chain characteristics and the loss a firm incurs is a result of its supply chain vulnerability to a given supply chain disruption”. Wagner and Bode (2009) further argue that supply chain characteristics are antecedents of supply chain vulnerability and have impact on both the probability of occurrence as well as the severity of supply chain disruptions.

<table>
<thead>
<tr>
<th>Author</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>Wagner and Bode (2006)</td>
<td>Supply chain vulnerability is a function of certain supply chain characteristics and the loss a firm incurs is a result of its supply chain’s vulnerability to a given supply chain disruption.</td>
</tr>
<tr>
<td>Wagner, Bode and Koziol, 2009</td>
<td>Susceptibility or predisposition to loss because of existing organizational or functional practices or conditions.</td>
</tr>
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<td>Supply chain characteristics are antecedents of supply chain vulnerability and have impact on both the probability of occurrence as well as the severity of supply chain disruptions.</td>
</tr>
</tbody>
</table>

Following on from Svensson’s (2001) broad analysis of supply chain vulnerability, we reviewed and classified the related research into holistic and atomistic categories. Svensson (2001, 2002) focuses on atomistic vulnerability. One demonstration of this is a conceptual framework of vulnerability found in the inbound and outbound logistics flows of an automotive assembler. The model he presented consisted of three principal components: source of
disturbance, category of disturbance, and type of logistics flow. This study is based on a two-phase process that includes in-depth interviews and statistical techniques. It has been reported that the vulnerability in the inbound logistics that flow from subcontractors, and the vulnerability in the outbound logistics that flow to customers, may be measured using five principal dimensions: service, level, deviation, consequence, and trend. This study found that focal firms have a higher level of vulnerability in their inbound flows than in outbound flows.

Another is the examination of companies’ perceptions of corporate vulnerability in supply chains. This study was done using qualitative analysis to investigate the areas, the causes, and the contingency plans of vulnerability in upstream and downstream supply chains of the automotive industry. It was found that subcontractors in this industry tend to be limited to myopic and vertical views of the aforesaid three examined elements of corporate vulnerability in upstream and downstream supply chains.

Tang (2006) finds that if an enterprise has no supply chain risk management method by which to take precautions against vulnerability, the competitive advantage will be lost. That research indicates that the supply chain vulnerability cannot be directly observed but can be obtained by monitoring the driving factors of supply chain vulnerability. The root causes of supply chain vulnerability are divided into three kinds: supply side, demand side, and supply chain structure vulnerabilities. Demand side vulnerability mainly occurs in the downstream supply chain, including customers, product characteristics, external logistics, and customer service distribution and transportation.

Wagner and Neshat (2009) also studied a holistic supply chain in Germany. They developed an approach based on graph theory to quantify, and hence mitigate, supply chain vulnerability. Quantitative analysis of supply chain vulnerability aids managers in assessing the vulnerability of their supply chains and comparing the effectiveness of different risk mitigation strategies. They suggest that it is necessary to understand more about the dynamic nature of supply chain vulnerability over time and the consequences of this approach and up to future research. In addition, they considered other methods that might suit the task. Overall vulnerability refers to the vulnerability of the whole supply chain system. Jüttner et al. (2003) thus define supply chain vulnerability as “the creation of poor results in the supply chain when risk origins and risk-driven factors lean toward mostly risk mitigation strategies.” We use Wagner and Bode’s definition as a reference. We define delivery vulnerability as: the properties of the delivery system construct the system’s sensitivity. This sensitivity, and its loss caused by risks to product delivery, comprises vulnerability.

3. METHODOLOGY

Fuzzy cognitive maps (FCMs) combine the cognitive maps of psychology and fuzzy relationships to explore the system association model. The structure uses the cognitive map concept to connect the positive and negative relationships between variables. The variable selection method is the expert questionnaire method. In relationship processing, the numerical interval method is used to define the relationship between two variables, and the matrix operations method uses the relationship of changes in fuzzy factors, and the changes in degree of influence.

A cognitive map consists of nodes representing the most relevant concepts in an objective environment (Axelrod, 1976). Through adding plus (+) and minus (−) signs, it allows the identification of the type of relationship (Athanasios, Tsadiras and Konstantinos, 2003) as being positive or negative. A positive relationship is where one concept has a positive impact on another concept, while a negative relationship is where one concept has a negative impact on
another concept. Guided by these representations, a cognitive map can be expressed through a calculation of an adjacency matrix showing the sign of the relationship. However, one major limitation exists in cognitive maps, that is, the restriction of quantifying causal relationships among variables. In order to overcome this weakness, fuzzy numbers were incorporated to form a new technique that was named fuzzy cognitive maps.

FCMs are essentially a modeling methodology rooted in a combination of fuzzy logic and neural networks. FCMs map the objective environment through concepts and causal relationships among concepts, which are developed by the experts who operate, supervise, or know the environment well enough as well as understand how the concepts behave under different circumstances. Each concept could represent an entity, a variable, and so on depending on the characteristics of the system. Causal relationships among concepts in that objective environment are developed through human experience and knowledge.

The graphical illustration of an FCM is similar to the cognitive map. FCMs also consist of nodes, signs but the additional element, directional and weighted arcs are incorporated into the map. Nodes in the graph stand for the concepts that describe the behaviors in the objective environment and they are connected by signed and weighted interconnections that represent the causal relationships among the concepts, as showed in Fig. 1.

![Figure 1. An example of a Fuzzy Cognitive Map with concepts and weighted causal relationship](image)

FCM calculations use a fuzzy value between −1 and 1. FCMs can be represented as Equation (1), with an n×n adjacency matrix (E) and where n is the number of nodes. By values within [−1, 1], each $w_{ij}$ means the strength of the causal relationship between the i and j concepts. Consequently, three types of relationships can be seen: (a) $w_{ij}>0$, indicating a positive relationship; (b) $w_{ij}<0$, indicating a negative relationship; and (c) $w_{ij}=0$, where no relationship exists.

$$
E = \begin{pmatrix}
  w_{11} & \cdots & w_{1n} \\
  \vdots & \ddots & \vdots \\
  w_{n1} & \cdots & w_{nn}
\end{pmatrix}
$$

(1)

When an expert assigns a $w_{ij}$ value, three issues must be kept in mind (Schneider et al., 1998). First, the $w_{ij}$ indicates how strong a causal influence the i concept casts on j. Second, the strength of relationship precedes a fuzzy weight with a positive or negative sign, representing whether that relationship is direct or inverse, respectively. Third, the causal relationship needs
to be shown to establish whether the $i$ concept is a cause of $j$ or vice versa. However, gaining consensus among the experts regarding FCMs is relatively difficult because every expert may have their own opinions, leading to explanatory difficulties.

Once the adjacency matrix is available, a new value for each concept that is calculated according to the following equation could be acquired:

$$W_i(t_{n+1}) = W[\sum e_{ki}(t_n)W_k(t_n)]$$

(2)

Here, $W_i(t_{n+1})$ is the value of concept $W_i$ at step $t_{n+1}$, $W_k(t_n)$ is the value of concept $W_k$ at step $t_n$, $e_{ki}(t_n)$ is the strength of the causal relationship from concept $W_j$ to concept $W_i$, and $S(x)$ is a bounded signal function that transforms the result of the multiplication in the interval $[0, 1]$. $S(x)$ is a threshold function that squashes the result of the multiplication in the interval $[0, 1]$. The logistic signal function has been used to transform to an S-shaped curve using the following Equation (3).

$$S(x) = \frac{1}{1 + e^{-\alpha x}}$$

(3)

FCMs are comparatively easy to quantify, and then indicate state transitions through a simple matrix calculation. Because of this advantage, FCMs have been applied to not only social science such as investment analysis problems (Lee and Kim, 2002), political problems (Athanasios, Ilias, and Konstantinos, 2003), and critical success factors modeling for an IT project process (Rodriguez-Repiso, Rossitza and Jose, 2007), but also to engineering problems such as behavioral analysis of electronic circuits (Styblinski and Meyer, 1998) and knowledge modeling for urban design (Xirogiannis, Stefanou and Glykas, 2004). In addition, FCMs have also been applied to strategic planning such as modeling political and strategic issues and situations (Andreou, Mateou and Zombanakis, 2005), and simulating the information systems of a strategic planning process. The areas of decision making, project management, and investment analysis have also used FCMs, for example, for relationship management in airline services (Kang, Lee and Choi, 2004).

4. DATA COLLECTION AND PROCESSING

4.1 Multinational Retailing Delivery System

In Taiwan there are many convenience stores, which facilitates retail deliveries (RDs) (shopping online and then picking up orders at convenience stores). RDs of e-commerce products in Taiwan is more than 10 years old, and the e-commerce RD model is mainly employed by providers. Providers have had to improve information flow both internally and externally, and integrate their logistics services into the RD service provided by convenience stores. The procedure, which combines E-tailing with the RD system is illustrated in Fig. 2. Briefly, the RD process is as follows:

1. Online shopping: Major e-tailers in Taiwan provide RD services. Some decide the delivery mode of the goods (home delivery or retailing delivery), and others provide consumers with their own choice of delivery mode.

2. Selection of pick-up point: When consumers choose an RD system, the convenience stores will be shown on the website. Consumers then select a pick-up point on the e-map provided by the RD system.
3. Packing process: E-tailers transmit the information about goods ordered to their distribution center, and personnel there are responsible for packaging and transporting the goods ordered to the convenience store delivery centers.

4. Delivery process: The convenience store delivery center collects the orders and transports them to different convenience stores. It then sends the processed order information back to the e-tailers.

5. Pick up goods: According to the information received from the delivery center, e-tailers will notify the consumers by e-mail or telephone about the pick-up. After that, consumers can pick up their goods. In general, consumers order goods on day D, and on day D+1 providers will start the packaging process. Consumers usually pick up their order at the selected convenience store on the afternoon of day D+2.

<table>
<thead>
<tr>
<th>Date (Time)</th>
<th>D day</th>
<th>D+1 day (00~15)</th>
<th>D+1 day (16~24)</th>
<th>D+2 day ~ D+9 day</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-line shopping</td>
<td>Packing process</td>
<td>Delivery process</td>
<td>Pick-up points</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 2. E-commerce RD model**

RD is used for the B2C business model. Recently, different patterns have been developed for the RD model, for example, store-to-store retailing delivery uses the C2C business model, whereby the seller (sender) and buyer (recipient) can use the store-to-store RD service for their logistics needs. The development of this logistics delivery model has provided a great deal of support to the C2C business model. Online stores can offer more delivery options for customers to choose from. Meanwhile, customers can make their own choices about which is the most
convenient approach to getting their products.

In 2012, FamilyMart (Taiwan) and Circle K (Hong Kong) integrated their information system and logistics system, providing a new RD model, the Multinational Retailing Delivery Service. Using the Multinational Retailing Delivery Service, online bookstores can provide their services to their customers in Hong Kong, and Hong Kong readers can choose books (or products) through the online bookstore in Taiwan, and pick up their books (or products) at Circle K (Hong Kong). Figure 3 describes the basic concept of the Multinational Retailing Delivery Service.

4.2 The Proposed FCM

The fuzzy cognitive map combines the cognitive maps of psychology and fuzzy relationships to explore the system association model. The structure uses the cognitive map concept to connect the positive and negative relationships between variables. The variable selection method is the expert questionnaire method. In relationship processing, the numerical interval method was used to define the relationship between two variables, and the matrix operations method uses the relationship of changes in fuzzy factors, and the changes in degree of influence.

The proposed fuzzy cognitive map is constructed according to the defined system scope and the problems they encounter. To build up the fuzzy cognitive maps to find insightful characteristics of the problems, the first step is to explore the concepts within fuzzy cognitive maps. From the in-depth interviews and literature review, this study constructed factors that influence the vulnerability of multinational stores and the logistics service system and conducted data collection through the expert questionnaire. We conducted a survey aimed at practicing experts with relevant experience in managing multinational stores and logistics service systems. The questionnaire survey design was set up through Taiwan FamilyMart’s delivery service and Hong Kong CircleK’s pick-up services.

Figure 4 explains the integrated supply chain management model of the case study. From Fig. 4, it can be seen that the main members making up the multinational convenience stores and logistics service system can be divided into supermarkets, and logistics, information, and multinational transportation businesses. In line with the results of the in-depth interviews and literature review, this study constructed 7 variables that influence the case study’s logistic vulnerability: “Lack of integration and coordination (X1)”, “Frequencies of regular meetings (X2)”, “Bad performance of customs procedure (X3)”, “Stability of multinational logistics (X4)”, “Stability of information system (X5)”, “Performance of retailing delivery (Taiwan), (X6)”, “Performance of retailing delivery (Hong Kong), (X7)” and “Vulnerability of multinational logistics (X8)”. Table 2 explains the definitions of the variables in the fuzzy recognition map.

In the proposed FCM, the directional arc represents the causal relationship. The dotted arcs will be activated if the value of the concept state is above or below the threshold. For example, if the “Frequencies of regular meetings” is high enough, the “Stability of multinational logistics” will be activated.
logistics” will then be perceived. As soon as the “Stability of multinational logistics” assets is activated, other related concepts will then be perceived (“Stability of multinational logistics” or “Performance of retailing delivery (Taiwan)”, and “Performance of retailing delivery (Hong Kong)”). Experts in this field will evaluate the concepts’ confirmation, the initial rating of concepts, and the strength of the causal relationship.

Figure 4. An example of a fuzzy cognitive map with concepts and causal relationship

Table 2. Definitions of the variables in the fuzzy recognition map

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitions of Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance of retailing delivery (Taiwan)</td>
<td>The procedure includes storage of goods at the supermarket, pick-up of goods by the delivery driver, transportation of goods to FamilyMart convenience stores’ logistics center, and transportation of goods to customs for clearance operations.</td>
</tr>
<tr>
<td>Bad performance of customs procedure</td>
<td>The procedure includes clearance operations after sending products to Taiwan Customs, followed by maritime transportation to Hong Kong after their shipping clearance operations.</td>
</tr>
<tr>
<td>Stability of multinational logistics</td>
<td>This variable refers to the following procedure: Goods are distributed through Taiwan Logistics Center to Hong Kong’s CircleK Logistics Center, where the products are relabeled, the logistics data are transferred, and distribution takes place.</td>
</tr>
<tr>
<td>Performance of retailing delivery (Hong Kong)</td>
<td>The process includes the categorization and distribution of the goods to the CircleK convenience store indicated by the consumer. The consumer goes to the Hong Kong CircleK convenience store to pick up the goods. After every completed logistical activity, each member of the multinational supply chain should return the status of the goods to inform members of the supply chain about the latest logistics data.</td>
</tr>
<tr>
<td>Stability of information system</td>
<td></td>
</tr>
</tbody>
</table>

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Table 2. Definitions of the variables in the fuzzy recognition map (con.)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Definitions of Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequencies of regular meetings</td>
<td>This variable refers to the development and coordination frequency of the daily mutual operations of multinational stores and of distribution and logistics supply chain members. When operation bottlenecks or unexpected situations are encountered, communication, development, and coordination frequency will increase.</td>
</tr>
<tr>
<td>Lack of integration and coordination</td>
<td>When abnormalities occur in a sector of the multinational stores and in the distribution and logistics system, multinational stores and supply chain members have emergency response capabilities.</td>
</tr>
<tr>
<td>Vulnerability of multinational logistics</td>
<td>This refers to the vulnerability of the Taiwan FamilyMart delivery and Hong Kong CircleK pick-up logistics system.</td>
</tr>
</tbody>
</table>

4.3 Sample Source and Output

The directional arcs between the concepts in Fig. 4 represent the strength of causal relationships, which are solicited and gathered through the survey process. Every expert is asked to fill in the values \( e_{ij} \) corresponding to the cells of the questionnaire. From the survey, we can establish an evaluation model for management strategies via the FCM. Each concept has a value, in the range of \([-1, 1]\) and the values of concepts correspond to real situations that experts would expect to occur. The final adjacency matrix is then given by a normalized sum according to Equation (4).

\[
W(t) = \frac{1}{n} \sum_{i=1}^{n} W_i(t)
\]  \hspace{1cm} (4)

In Equation (5), \( x_i(t) \) represents the status of period \( t \) in variable \( i \); the values of \( x_i \) range between 0 and 1. The closer variable \( x_i \) is to 1, the better the status of variable \( x_i \) (or worse according to the variable’s definition and differences). The variable \( w_{ji} \) is the weight value of variable \( j \)'s influence on variable \( i \); the values of \( w_{ji} \) will be less than 1, positively representing that variable \( j \) has a positive influence on variable \( i \) and negatively representing that variable \( j \) has a negative influence on variable \( i \). Thus, the higher the value of \( w_{ji} \), the higher the degree of influence. In Equation (1), the status of period \( t+1 \) in variable \( X_i \) is determined by the status of all the variables at period \( t \) influencing variable \( X_i \). The conversion function \( f \) makes sure every iteration of the fuzzy cognitive map converges to the variable range of the initial range set, and converts the value of \( x_i(t) \) to a value between 0 and 1. In this paper, we chose the logistical signal function as the conversion function. The common range setting of parameter \( \lambda \) is 0.2–5. The setting of \( \lambda \) is related to variable amounts in the fuzzy cognitive map and the complexity between variables. According to the characteristics setting in the fuzzy cognitive map, this study’s \( \lambda \) value is set as 2.

\[
x_i(t) = f \left( \sum_{j \neq i} w_{ji} x_j(t-1) \right), f = \frac{1}{1 + e^{-\lambda x_i(t)}} \]  \hspace{1cm} (5)

For the questionnaire respondents, we chose 10 supply chain members who were experts having managerial positions or higher. In the study’s questionnaire format, these experts were invited to write the status of each variable, and the degree of influence each variable has on the
other variables. According to the data collection and processing, the data gathered and operated is as in Table 3. The weight matrix for the FCM could be produced: showing a negative impact, no impact, or a positive impact, and revealing the strength of impact to concepts in each column compared with those in each row, the values range between 0 and 1. The closer they are to 1, the higher the degree of influence. Positive values represent that the influence is positive, and negative values represent that the influence is negative. The value interval of the status variable is 0–1. The closer the value of the status variable is to 0, the worse the system status is (or better, depending on the definitions of the variables). When the value of the status variable is 1, this represents that the status of the variable is the better (or worse depending on the definitions of the variables).

### Table 3. The input data

<table>
<thead>
<tr>
<th></th>
<th>$X_1$</th>
<th>$X_2$</th>
<th>$X_3$</th>
<th>$X_4$</th>
<th>$X_5$</th>
<th>$X_6$</th>
<th>$X_7$</th>
<th>$X_8$</th>
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</tr>
</thead>
<tbody>
<tr>
<td>$X_1$</td>
<td>0.30</td>
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</tbody>
</table>

In addition, the questionnaire asked about not only the strength of the impact but also asked for a rating (or the initial state, $S_0$) of the concepts’ state. The acquired value is confined to the interval $[-1, 1]$, showing a negative relationship, no relationship, or a positive relationship, and revealing the strength of causal relationships to concepts in the corresponding column and row. Besides, not only the impact of strength but also the initial rating (initial state, $W_0$) of the concepts’ state is also inquired. The rating of the concept state represents the respondents’ assessment of the current state. Its interval falls within $[0, 1]$. All the experts were consulted, with their experience and knowledge evaluated on a numerical scale. In order to avoid illogical deviation and error, each value in the survey cell was rigorously checked to ensure that the value difference in each cell of every survey was within a reasonable range. Verification as to whether the value conflicts with prior experience was also implemented as a result.

The output of the proposed FCM is shown in Table 4 and Fig. 5. After taking into account that the concepts incorporated need time to ferment in the real world, each run is assumed to be one week. In practice, each member of the multinational retailing delivery system usually needs about one week to respond to any changes. The interviewed experts indicated that when the multinational logistics system encountered changes from the external environment and needed to change, the time needed to prepare and change the results was about a week. Procedures that are implemented during that week include: (1) holding a meeting to determine the contents of operations that need to be repaired, (2) contacting the relevant unit making operational adjustments, and (3) announcing the changes to all units and starting to implement new operations. In addition, in a study on logistics operations, Wang et al. (2010) set each iteration of the fuzzy cognitive map to a week, as the managers implied. Therefore, in referring to the interviewed experts and the study’s literature review of definitions, we set each iteration calculation to a week, as indicated by the managers.

The results reflected in Fig. 5 indicate that:

1. The “frequencies of regular meetings” variable was increased at the first run, and then decreased during 10–20 weeks; then, after 20 workdays, it gradually increased, before dropping back down a bit after about 40 weeks. This would likely explain that the poor performance of
customs procedures was not stabilized at the beginning. After 40 weeks, the poor performance of customs procedures closed at 0.38, indicating that the frequencies of regular meetings will have almost no effect in the long run.

(2) Poor performance of customs procedures and lack of integration and coordination. After 20 weeks, these slowly increased and finally closed at 0.46 and 0.38.

(3) “Performance of retailing delivery (Taiwan)”, “Performance of retailing delivery (Hong Kong)”, “Stability of information system”, and “Stability of multinational logistics” all increased, then showed minor decreases and finally stabilized at 0.76, 0.74, 0.85, and 0.85, respectively.

(4) Vulnerability of multinational logistics decreased until three runs, and dropped to 0.11 after 30 weeks.

![Figure 5. Result of FCM](image)

**Table 4. Final State for each variable of FCM**

<table>
<thead>
<tr>
<th></th>
<th>$X_1$</th>
<th>$X_2$</th>
<th>$X_3$</th>
<th>$X_4$</th>
<th>$X_5$</th>
<th>$X_6$</th>
<th>$X_7$</th>
<th>$X_8$</th>
</tr>
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<tbody>
<tr>
<td>State ($S_0$)</td>
<td>0.60</td>
<td>0.50</td>
<td>0.30</td>
<td>0.70</td>
<td>0.67</td>
<td>0.75</td>
<td>0.65</td>
<td>0.43</td>
</tr>
<tr>
<td>State ($S_{24}$)</td>
<td>0.43</td>
<td>0.46</td>
<td>0.39</td>
<td>0.86</td>
<td>0.86</td>
<td>0.77</td>
<td>0.75</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Fig. 4 shows the FCM, the variable including “Lack of integration and coordination ($X_1$)”, “Frequencies of regular meetings ($X_2$)”, “Bad performance of customs procedure ($X_3$)”, “Stability of multinational logistics ($X_4$)”, “Stability of information system ($X_5$)”, “Performance of retailing delivery (Taiwan) ($X_6$)”, “Performance of retailing delivery (Hong Kong) ($X_7$)”, and “Vulnerability of multinational logistics ($X_8$)”.

### 4.4 Sensitivity Model Analysis

The methodology derives from bio-cybernetics and incorporates feedback loops to check and balance the system performance with the analogy of symbiotic relationships between humans and the environment (Vester, 1988). The sensitivity model is a semiquantitative modeling tool based on system thinking and fuzzy logic, developed in the 1975 UNESCO program, Man and
the Biosphere (MAB II). It has been used by major corporations such as IBM, Siemens, Daimler-Benz, Hoechst, as well as governmental agencies and academic institutes (Chan and Huang, 2004; Ulrich, 2005). The fundamental ideas of SM, differing from other planning approaches, include system thinking, the use of fuzzy set theory, and simulation through semiquantitative data (Chan and Huang, 2004). Sensitivity analysis according to Vester has been applied in diverse areas, including urban and regional planning. There are many references where the method has been successfully applied to different fields of research, including regional and environmental planning and risk management.

After compiling the impact matrix, this leads to an output table of systemic characteristics and a graphic display of the relations among the concepts. This step is based on a pair-wise comparison, in which each concept and each criterion are arranged in an impact matrix as shown in Table 5. In the sensitivity model, the effect can be classified as of no significance, low significance, medium significance, and high significance, and expressed as 0, 1, 2, and 3 respectively. Each cell in the impact matrix aims to examine the direct influence of the vertical variable (column variable) on the horizontal variable (row variable). The values in the last two columns and rows of the impact matrix (Table 5) provide us with needed information to identify the role for each variable in the system.

Then, this paper explored the fuzzy cognitive map through the sensitivity model. The variables act as key influencing factors. In the influence weight matrix, active sum (AS) represents the sum of variables that influence other variables. The greater the AS value of variables is, the greater the degree to which a variable influences other variables. Passive sum (PS) represents the degree to which a variable receives the influence of other variables. The variable Q is the ratio of AS/PS. The greater the Q value is, the more difficult it is for the variable to influence other variables and to receive the influence of other variables. According to AS and PS, sensitivity can be obtained in the fuzzy cognitive map. The further the variable is from the original point, the more that the size of the Q value can represent the area size of the variable, as shown in Fig. 6.

<table>
<thead>
<tr>
<th></th>
<th>X_1</th>
<th>X_2</th>
<th>X_3</th>
<th>X_4</th>
<th>X_5</th>
<th>X_6</th>
<th>X_7</th>
<th>X_8</th>
<th>AS</th>
<th>Q</th>
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<tbody>
<tr>
<td>X_1</td>
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<td>3</td>
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<td>2</td>
<td>3</td>
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<td>1</td>
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<td>3</td>
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<td>2</td>
<td>14</td>
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<tr>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>0.7</td>
</tr>
<tr>
<td>X_4</td>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>5</td>
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<tr>
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<td>0</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>11</td>
<td>1.0</td>
</tr>
<tr>
<td>X_6</td>
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<td>0</td>
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<td>0</td>
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<td>2</td>
<td>8</td>
<td>1.0</td>
</tr>
<tr>
<td>X_7</td>
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<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>0.8</td>
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<td>X_8</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0.3</td>
</tr>
<tr>
<td>PS</td>
<td>3</td>
<td>13</td>
<td>9</td>
<td>7</td>
<td>11</td>
<td>8</td>
<td>8</td>
<td>11</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

This study used AS and PS to represent a one-directional effect. When summing up the numbers of one row to the right, we get the active sum (AS) of the corresponding variable. It represents how strongly any concept affects other concepts of the system. We also add the numbers in a column and get the passive sum (PS) of a variable, showing the extent to which the concept is affected by other concepts. If a concept has a relatively high AS, e.g. “Lack of integration and coordination” (17), any change in that concept would significantly impact the system. In contrast, if the AS of a concept is a small number, this concept has to change dramatically before it produces a significant effect on the other concepts of the system, e.g. Stability of multinational logistics (2). A high PS such as that for the relationship with suppliers
means that as soon as something happens within the system, this concept will be affected significantly. On the other hand, a small PS means that within the system, many phenomena can change without changing this concept.

AS and PS might explain the relationship between active and passive directional effects. There are two other indices that are useful in describing the role of a concept in a system, i.e. P and Q. P, the product of AS and PS, represents a concept that plays a primary role. Q, the quotient of AS over PS describes the distinct role of a concept. A variable with a high quotient value (Q) and a high product value (P), such as “Performance of retailing delivery (Taiwan)” means that it is an important concept in the system. With the aid of P and Q, we can interpret the role of the concept of the system more synthetically. This provides us with the first strategic indications by expressing the four indices (AS, PS, P, Q) in a conceptual context. By their location within this grid, the fields depict the roles of the concepts.

Figure 6 illustrates what happens in the model, where each of the concepts is located along the four indices AS, PS, P, and Q, which creates a field of tension between active, critical, reactive, and buffering. Here, a concept above the line means that the concept strongly effects the other concepts, whereas a concept under the line means that the concept is affected by other concepts. According to the above rules, all the concepts of the system are plotted in Fig. 6. We can see that “Lack of integration and coordination”, “Frequencies of regular meetings”, and “Stability of multinational logistics” are the critical concepts in the multinational retailing delivery system, which means that these concepts are the major driving force behind development of the system.

![Figure 6. System roles of the variables](image)

5. CONCLUSIONS AND SUGGESTIONS

Along with the external environment’s continual changes, the topic of risk management has extended to become the focus of supply chain research scholars. This paper analyzes the extremely complex procedure of the operations of the multinational stores and distribution
logistics mechanism. The procedures deal with many uncertain factors that lead to operational risks. Therefore, how to decrease the vulnerability of the system itself and increase the system’s recovery ability has become an important topic for supply chain risk management. In the future, all industry supply chain systems will face many challenges. Along with the development of related technologies in logistics and distribution, the derived logistics service patterns are also becoming increasingly diverse. The logistics industry cannot avoid encountering more cross-industry competition. In facing these external environment changes, each industry’s supply chain management personnel must develop the industry’s supply chain risk identification and evaluation indicators.

Because of great developments in electronic commerce, online shopping has become more and more popular. Many marketing experts believe that websites are the most important retail channel. Online trade is not only business to customer (B2C, where a company provides a service to the customer), but also customer to customer (C2C, where a customer provides a service to another customer). That is, people can buy or sell their own property through e-commerce systems such as e-auctions. The E-tailing is obviously becoming a noticeable market. However, as the market grows and matures, “delivery service failure” becomes one of the challenges for e-tailers. With the increase of e-transaction volumes between Taiwan and China (Hong Kong) and based on the Economic Cooperation Framework Agreement, the retailing delivery providers in Taiwan upgrade the service and become part of the transnational retailing delivery service mechanism. To better understand the vulnerability of transnational delivery systems, we used FCM and SM to analyze the vulnerability of our case. In this study, we first described the basic concept of a multinational retailing delivery system, and second, we developed a FCM model to analysis the vulnerability of the research case. Variables used in the FCM included “Lack of integration and coordination”, “Frequencies of regular meetings”, “Poor performance of customs procedures”, “Stability of multinational logistics”, “Stability of the information system”, “Performance of retailing delivery (Taiwan)”, “Performance of retailing delivery (Hong Kong)”, and “Vulnerability of multinational logistics”. Finally, according to sensitivity model analysis, we showed that the “Lack of integration and coordination”, “Frequencies of regular meetings”, and “Stability of multinational logistics” are the critical concepts in this multinational retailing delivery system, which means that these concepts are the major driving force behind system development.

The results obtained in this study can be used to improve the delivery service quality for delivery providers and evaluate the delivery quality management strategies. Based on the research process and results as shown previously, some work still remains to enhance the research quality. One of the key research opportunities and recommendations for further research is finding the relationship among the variables of the FCM that may exhibit nonlinear or chaotic behavior; this is an interesting research topic for future research. In addition, there are several different models of multinational retailing delivery systems. In our case (a Taiwan–Hong Kong), the model we use was a B2C business model. Future researcher can consider the case of Taobao (Taiwan–China), representing a C2C business model. Taobao’s growth rate is quite fast, and a C2C model is more complex than a B2C model. The case of Taobao will be a very important case.

ACKNOWLEDGMENTS
This work was supported by the National Science Council of Taiwan through a research grant (MOST 104-2410-H-343-011).
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