EXPLORING 24-HOUR DELIVERY THROUGH A FUZZY COGNITIVE MAP MODEL -A CASE STUDY OF PCHOME.COM

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1. Introduction

The service of shopping on-line in an electronic store and picking up goods at home could be quite common and popular these days. In the beginning, online shopping provided goods not time sensitive. With the mature of service in recent years, daily necessities and PC appliances become also available. Therefore, the speed has become an important factor enough to accomplish the 24-hour delivery service. Generally, the previous studies use Optimization or Analytic Network Process (ANP) to accelerate the speed. Here, it differs from previous studies to find out the relations between the important concepts for the 24-hour delivery service, and to compute the "strength of relationships" among these concepts. The literature for on-line shopping will be reviewed, and the key factors for accomplishing 24-hour deliveries will be found, via experts' in-depth interviews. The relationship between those factors will be analyzed by using FCM method. This study proposed some solutions to achieve and improve 24-hour delivery service eventually.

2. Literature Review

Consumers worldwide can shop online 24 hours a day, seven days a week, and 365 days a year. With regard to the relationship between online searching and buying, research results show that searching online positively affects buying online (Bellman, S., Lohse, G.L., & Johnson, E.J., 1999). Searching online positively affects the frequency of shopping trips, which in its turn positively influences buying online. These findings suggest that e-shopping could be a time-saving strategy for some people, and leisure-oriented for others. Urban residents shop online more often than suburban residents, because they tend to have a faster Internet connection (Farag, Sendy, Tim, Martin, & Jan 2007).

Sensitivity model (SM) is based on bio-cybernetics and incorporates feedback loops to check and balance the system performance with symbiotic relationships between humans and the environment (Vester, 1988). It is a semi-quantitative modeling tool based on systems thinking and fuzzy logic (Chan & Huang, 2004).

Cognitive map (CM) is a symbolic method for modeling and controlling a system which relies on expert experience and follows the principle of "decreasing precision and increasing intelligence". For this reason, CM enable decision-makers to analyze the potential casual relationships among concepts which can help reach more significant and meaningful solutions. Fuzzy cognitive map (FCM) is an extension of CM, and it is useful in modeling complex systems (Peter P. & Chrysostomos., 2001). Moreover, it specifies the causal relationship among concepts and depicts the causal links. The CM studies the perceptions about the real world and the way they act to attain human desires. Example systems include Web-mining systems (Lee, Kim, Chung, & Kwon, 2002).

The fundamental ideas of SM and FCM, which make them different from other planning approaches, include system thinking, and the use of fuzzy set theory. The SM was by no means used for the first time in logistics, and here use SM to make sure if all these problems are included. The present study applies the methodology FCM to model and explore the operation for 24-hour delivery. The system model developed here can be used to study the effects of any parameter change on the stability and growth of the remaining parameters. It specifies the causal relationship among concepts, then, helps an e-shopping company to implement the strategies of 24-hour delivery in a global and systematic view.

3. Construction of 24-hour Delivery

(1) An Overview of 24-hour delivery

In Taiwan, Yahoo.com and PChome.com currently provide 24-hour delivery services for their on-line customers, and have made many remarkable successes. The 24-hour delivery service provides consumers with shopping on-line service in an electronic store and picking up goods within 24 hours.

(2) Introduction 24-hour delivery model

The procedure that combines PChome with EZ-Cat system about 24-hour delivery is illustrated below:

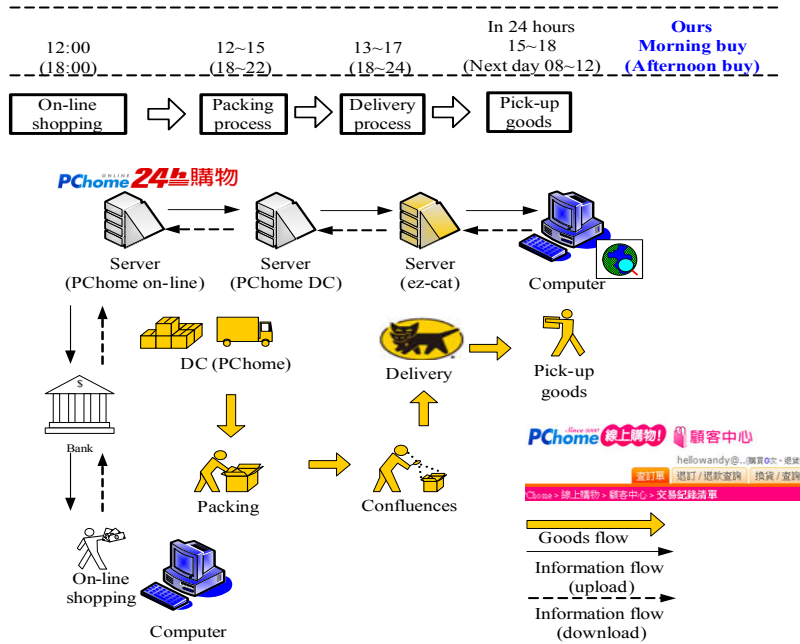

Figure 1: The 24-hour delivery model

a) On-line shopping: Consumers are shopping on-line via the Internet. The PChome online has a specialized area for 24-hour delivery goods, and all the goods in the area can be picked up quickly within 24 hours.

b) Packing process: The PChome transmits the information of the ordered goods, and begins packaging process and transports the goods to the delivery center.

c) Delivery process: The delivery center of PChome will collect the orders and EZ-Cat will transport them to customers, and then it will reply the processed order information to the server of PChome.

d) Pick-up goods: Consumers can see the delivery processed which is shown on the website. According to the information replied from delivery center, the EZ-Cat will notify the consumers by e-mail or phone call for the pick-ups.

(3) Defining Criteria and Concepts

In order to build up SM and FCM to acquire the insightful characteristics of the problems, the first step is to explore the concepts within these two methods. In the process of field trips and in-depth interviews, there are four categories of the criteria: purchasing category, logistics service category, image category, and information category; criteria are identified as follows:

Table 1: The criteria identified

Purchasing category	Logistics service category	Image category	Information category
Web Interface	Logistics Service Flexibility	Promotion	Information flow exchange
Product Category	Timeliness	Dealing with Timeliness	Inventory fulfillment notice
Maturity of 24-hour delivery model	Order Condition	Order Discrepancy Handling	Instability Information System
		Service Attitude	

The identified problems and the causes behind them are considered as the following concepts:

Table 2: The concepts identified

(A)Order of 24-hour delivery service	(B)Logistics Performance	(C)Relationship with suppliers	(D)Product Category	(E)Ability to achieve 24-hour delivery
(F)Time window problem	(G)Information System	(H)Lack of ability to develop information system	(I)The resilience of safety stock	(J)Stable operation of warehouse

4. Methodology

After defining the concepts, then we find out the relationships among them and construct a model.

(1) Sensitivity Model(SM)

Sensitivity model is a semi-quantitative modeling tool based on systems thinking and fuzzy logic. Follow the defined concepts and criteria of SM, the instrument consists of two main parts. One is the criteria matrix, the other is impact matrix.

a) The Criteria Matrix

The Criteria Matrix is applied to check the completeness of system in four categories of criteria. Each category contains several sub-criteria that there are 13 items in total. Each concept of system variables was evaluated against the 13 criteria, and the matrix was asked to fill out 0, 0.5, or 1 to show not applicable, partly applicable or fully applicable, respectively.

Table 3: The Criteria Matrix Value

Categories	Purchasing Category			Logistics Service Category			Image Category				Information Category		
Criteria / Concepts	Web Interface	Product Category	Maturity of 24-hour delivery model	Logistics Service Flexibility	Timeliness	Order Condition	Promotion	Dealing with Timeliness	Order Discrepancy Handling	Service Attitude	Information flow exchange	Inventory fulfillment notice	Instability Information System
A. Order of 24-hour delivery service	0.8	1.0	0.1	0.8	0.9	0.7	0.9	0.6	0.5	0.9	0.6	0.6	0.9
B. Logistics Performance	0.0	0.6	0.9	0.7	1.0	0.9	0.1	1.0	0.8	0.9	0.9	0.0	0.7
C. Relationship with suppliers	0.0	0.7	0.6	0.0	0.6	0.5	1.0	0.5	0.6	0.6	0.0	0.0	0.0
D. Product Category	0.6	0.8	0.7	0.6	0.7	0.6	0.9	0.4	0.4	0.5	0.0	0.0	0.0
E. Ability to achieve 24-hour delivery	0.3	0.6	1.0	1.0	0.9	0.7	0.6	0.6	0.6	0.6	1.0	0.6	0.8
F. Time window problem	0.4	0.1	0.1	0.7	0.1	0.0	0.6	0.9	0.1	0.0	0.9	0.0	0.4
G. Information System	0.9	0.0	0.6	0.6	0.8	0.1	0.0	0.6	0.1	0.1	1.0	0.9	1.0
H. Lack of ability to develop information systems	0.7	0.0	0.0	0.0	0.6	0.0	0.0	0.4	0.4	0.2	0.9	0.9	0.9
I. The resilience of safety stock	0.0	0.9	0.7	0.8	0.9	0.0	0.7	0.1	0.1	0.6	0.8	0.8	0.1
J. Stable operation of warehouse	0.1	0.6	0.6	0.9	0.9	0.9	0.5	0.1	0.1	0.0	0.1	0.7	0.1
Sum (Score of sub-category)	3.8	5.2	5.3	6.0	7.3	4.5	5.3	5.1	3.6	4.3	6.2	4.6	5.0

In Table 3, the higher scores "Timeliness" (7.3) and "Information flow exchange" (6.2) are important factors of system development. High values in the column of "Timeliness" (7.3), "Logistics Service Flexibility" (6.0) and "Order Condition" (4.5) in the Logistics service category tell us that material entities such as (A) Order of 24-hour delivery service, (B) Logistics Performance and (I) Resilience of safety stock are major components of 24-hour delivery system. In addition to these internal characteristics of the system, the high scores within the last three criteria of the category of information (6.2, 4.6 and 5.0) remind us that it is an open system and we should also take the external factors in the process of policy formulation into account.

b) The Impact Matrix

This step is based on a pair-wise comparison of each concept are arranged in an impact matrix as shown in Table 4. The effect is classified into no significance, low significance, medium significance and high significance, and expressed as 0, 1, 2, and 3 respectively. The value in each cell in Table 4 is obtained as averaged value from the survey on 7 experts. Each cell in the impact matrix aims to investigate the direct influence of the column concept on the row concept. The values in the last three columns and a row of the Impact Matrix provide us with the information to identify the role of each variable in the system.

Table 4: The Impact Matrix

	A	B	C	D	E	F	G	H	I	J	AS	P	Q*100
A. Order of 24-hour delivery service	0	1.7	2.4	0	0	0	2.7	0	1.4	2.0	10.3	86.7	122.0
B. Logistics Performance	0	0	1.6	1.3	0	2.6	0.1	0	0	0	5.6	34.2	90.7
C. Relationship with suppliers	2.0	0	0	0	0	0	0	0	0	1.7	3.7	45.6	30.2
D. Product Category	2.4	0	1.9	0	1.0	0	0.4	0	2.0	2.0	9.7	30.5	309.1
E. Ability to achieve 24-hour delivery	1.4	3.0	1.6	0	0	2.7	0	1.1	0	0	9.9	50.7	191.7
F. Time window problem	1.1	1.4	1.4	0	1.1	0	0.9	1.4	0	1.3	8.7	8.8	127.0
G. Information System	0	0	0	0	0	0	0	0	0.6	0.1	0.7	3.6	14.3
H. Lack of ability to develop information systems	0	0	0	0	0	0	0.9	0	0.3	0	1.1	2.9	44.4
I. The resilience of safety stock	1.4	0	1.9	1.4	1.3	0.9	0	0	0	1.7	8.6	51.4	142.0
J. Stable operation of warehouse	0	0	1.6	0.4	1.7	0.7	0	0	0	0	4.4	31.6	62.0
PS	8.4	6.4	12.3	3.1	5.1	6.9	5.0	2.6	6.0	7.1			

This study used AS and PS to represent one directional effect. When sum up the numbers of one row to the right, we get the active sum (AS). It represents how strongly any concept affects on the other concepts of the system. If a concept has a relatively high AS, like (A) Order of 24-hour delivery service (10.29), any change in that variable had significantly impact on 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. The result shows a striking effect of (G) Information System (0.71); including information accuracy, information flexibility, the speed of information, and information security on the system. We also add the numbers in a column and get the passive sum (PS), showing the extent to which the concept is affected by other concepts. A high PS such as (C) Relationship with suppliers (12.29) 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, a lot of phenomena can happen without changing this

variable, e.g. (H) Lack of information systems development capabilities (2.57). It may be due to PChome company is not a computer design company; more emphasis are put on how to sell the goods quickly, so less on the development of information systems.

Figure 2 illustrates what happens in that model, each of the variables is located along the two indices AS, PS, which creates a field of tension between active and reactive.
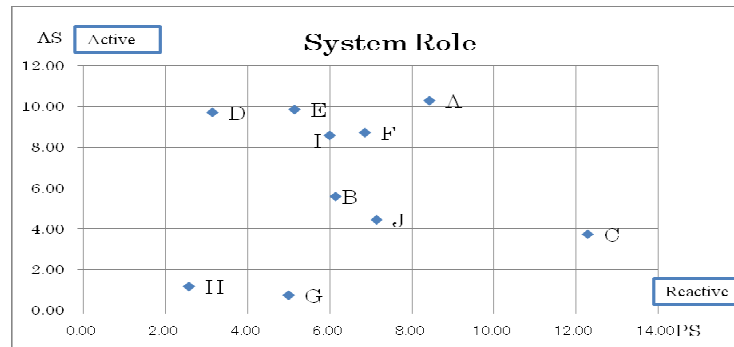

Figure 2: System roles of the variables

There are two other indices useful for describing the role of a variable in a system, P and Q. P, the product of AS and PS, represents the variable plays a primary role. Q, the quotient of AS over PS, is for describing the clear role of a variable. A variable with a high quotient value (Q) and a high product value (P), such as (A) Order of 24-hour delivery service means that it is an important variable in the system. Since high P-value, we can find out that (A) Order of 24-hour delivery service, (E) Ability to achieve 24-hour delivery, and (I) The resilience of safety stock are the critical variables in 24-hour delivery system, which means these variables are the major driving force of the system development.

(2) Fuzzy Cognitive Map (FCM)

FCM is a matrix computing process, expressing the variables change, and the data can be efficiently collected by questionnaire design in a short time. The experts' opinions in various fields will be associated and integrated into set of methods in order to expression of the entire system. The constructed FCM is decided by each concept, with each other concept, it will be connected and the sign of each interconnection.

a) Fuzzy logic

The concept of linguistic variable plays a major role in many applications of fuzzy set theory. The linguistic variable defuzzified value is according to center of gravity method (see eq. (1)).

$$S_k = \frac{a_k + b_k + c_k}{3}$$
(1)

Table5: The triangular fuzzy number.

Linguistic variable	The triangular fuzzy number
strong influence	(0.87 , 0.92 , 1.00)
medium influence	(0.53 , 0.66 , 0.87)
little influence	(0.23 , 0.28 , 0.53)
no influence	(0.00 , 0.00 , 0.23)

Table 6: The defuzzified value.

Linguistic variable	The defuzzified value
strong influence	0.93
medium influence	0.69
little influence	0.35
no influence	0.08

b) Data Consistency Verification

In logic, a consistent theory is one that does not contain a contradiction. In order to avoid illogical deviation, the verification of whether the value conflicted with prior experience is executed.

Table 7: The Data Consistency Verification

	A	B	C	D	E	F	G	H	I	J	Status
Professor	0.95	0.96	0.83	0.93	0.94	0.91	0.88	0.97	0.95	0.95	0.98
Management 1	0.89	0.91	0.97	0.96	0.85	0.92	0.93	0.73	0.95	0.96	0.96
Management 2	0.97	0.97	0.83	0.93	0.92	0.87	0.88	0.73	0.93	0.96	0.88
Management 3	0.88	0.81	0.12	0.78	0.76	0.91	0.69	0.59	0.71	0.50	0.98
Management 4	0.90	0.95	0.83	0.88	0.86	0.75	0.31	0.70	0.93	0.84	0.80
Management 5	0.88	0.96	0.12	0.90	0.91	0.67	0.88	0.54	0.82	0.90	0.92
Management 6	0.94	0.93	0.83	0.99	0.84	0.80	0.88	0.97	0.98	0.96	0.98

Each value in the cells of survey is checked to ensure that they are within a reasonable interval. The current status of each expert was given high degree of consistency assessment value as reflected in Table 7. The correlations between concept C's effect, management 3 and management 5 were strikingly different with the low degree of consistency. The low correlation of 0.31

between concepts G's effect, shows that management 4 has no strong relationship with others. Overall, the results have been very positive, and Table 7 reflected that the data have high degree of consistency with A, B, D, E, F, I.

c) The Framework of FCM

In order to deal with the problem of dependence and feedback among concepts, we first depict the FCM as shown in Figure 3 to illustrate the relationships among key concepts for 24-hour delivery, and the weights between concepts can be shown with different color arrows. The black arrow means that concept has positive effect on the other concept; in contrast, the red arrow means that concept has negative effect on the other concept. Several findings are of interest: Concept A has striking effects on B, C, G and J. Concept B impacts D and negative effect on F. If (B) Logistics performance is good, the (D) product category will increase, but that also means (F) time window doesn't need so much better. Concept C influences concept A and I markedly. (C) Relationship with suppliers is a critical factor that impacts whether (A) how many the suppliers would transfer the orders to 24-hour delivery of PChome.
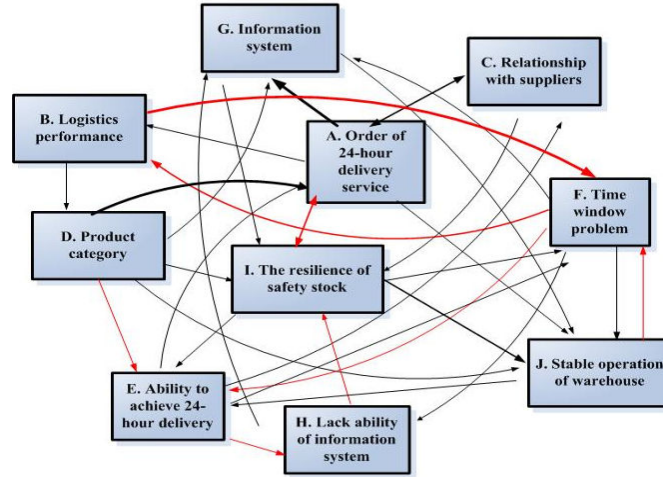

Figure 3: The initial FCM for 24-hour delivery

d) The Processing of FCM

At each simulation step of the FCM, the value of concepts is calculated according to eq. (2). Where $C_i(t_{n+1})$ is the value of concept C_i at step t_{n+1}, $C_k(t_n)$ is the value of concept C_k at step t_n, and $W_{ki}(t_n)$ is the weight of the interconnection from concept C_k to concept C_i. S(x) is a threshold function that squashes the result of the multiplication in the interval [0, 1]. It sets the constant for 5 has been used to transform an S-shaped curve.

$$C_i(t_{n+1}) = S\left(\sum_{k=1, k \neq i}^{n} w_{ki}(t_n)C_k(t_n) \right) \tag{2}$$

$$S(x) = \frac{1}{(1 + e^{-5x})} \tag{3}$$

From eq. (2), k doesn't equal to i, it means that concept consider about auto effect from themselves. In order to clarity if the concept consider about themselves is good or not, we tested base on eq. (4). Where β_j represents the weight of other concepts, and $(1 - \beta_j)$ represents how they consider themselves.

$$C_j(t_{n+1}) = \beta_j S\left(\sum_{k=1, k \neq j}^{n} w_{kj}(t_n)C_k(t_n) \right) + (1 - \beta_j)C_j \tag{4}$$

e) The output of FCM simulation

It has to be stressed that the study observes if there is no sudden accident to the case company, it will survive as time flows that illustrates what happens in that model. We could observe that the value of each concept will vibrate, and when the vibration will be stable. In addition, it is important to emphasize that the concepts incorporated need to ferment to real world in the research design. Each run is assumed to be 5 workdays; means that PChome needs about 5 workdays to respond all the condition changes.

Figure 4 illustrates the concept consider about themselves for $(1 - \beta_j)$ equal to 0.5. It indicates that the system was not stability at the beginning, such a partial explanation for this may lie in the fact that the (D) product category is not stable. To increase the (A) order of 24-hour delivery and improve the (E) ability to achieve 24-hour delivery, we need about 10~25 workdays to adjust. After

30 workdays, we find that the Ability to achieve 24-hour delivery is steady at 0.88 in the long run.

Figure 5 illustrates the concept consider about themselves for $(1-\beta_j)$ equal to 0.95. Compare to Figure 5, we find out the system needs 36 runs to achieve the goal. The result indicated that the more you consider on each factor independently, the system will be slower to improve. Considering the overall promotion significantly accelerates the improve process.
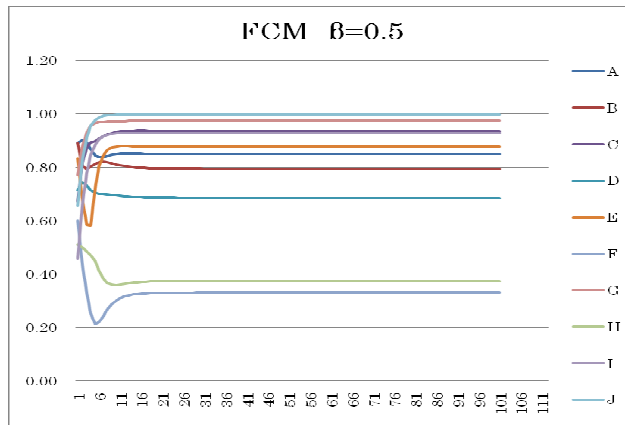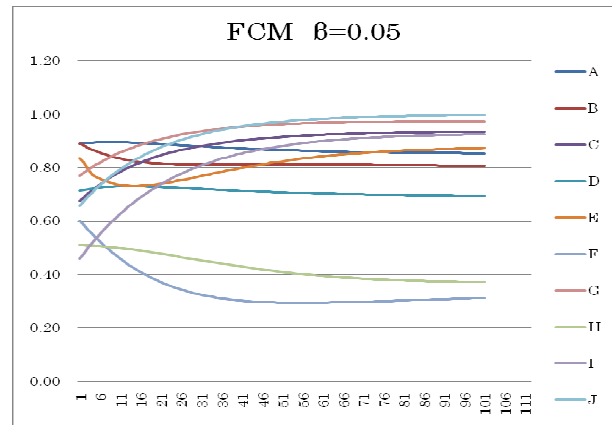

Figure 4:The output of   FCM(β=0.5)   Figure 5:The output of   FCM(β=0.05)

5. Conclusions and Suggestions

In conclusion, SM and FCM could be used for systematic studies both as an instruction tool and research tool. Through the literature reviews and in-depth interviews as well as discussions with experts, this research constructs 10 concepts and 13 criteria among them to find out about the relationship of 24-hour delivery.

The reported in this paper have demonstrated that these two systems can be practically implemented, and hope to applicative to the other company. The findings of this study lead to a number of implications. (A) Order of 24-hour delivery service, (B) Logistics Performance and (I) Resilience of safety stock are major components of 24-hour delivery system. The order of 24-hour delivery service is strongly affected by the (C) Relationship with suppliers. (C) Relationship with suppliers is a critical factor that impacts whether how many the suppliers would transfer the orders to 24-hour delivery of PChome. Keeping good relationship with the suppliers plays an important role for PChome can offer to meet customers' satisfaction. From SM tell us the Information system is important, the more likely explanation is that (H) Lack of ability to develop information system may be due to PChome company is not a computer design company, the possible solution is considering outsourcing to other information industry. The result revealed that the ability to achieve 24-hour delivery is steady at 0.88 in the long run. It is recommended that the approach outlined in this study be replicated in other e-shopping or third party companies.

The SM and FCM were chosen as the design methodology because they can be easily interpreted, since they clearly show the relationships between the different concepts and, at the same time, it is relatively easy to add or remove concepts, whenever necessary. The assumption that the simulation per run is set to be 5 workdays is a controversial issue in practical research. In the meantime, the simulation could be more complicated issues to discuss more.

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