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# Vulnerability and Resilience Analysis by Fuzzy Cognitive Map

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**ABSTRACT**

**Risk management is one of the primary concerns in financial institutions. The study introduces the concepts of "vulnerability" and "resilience" to construct the fuzzy cognitive maps for risk evaluation. Other than exploring the type of risk that the financial institutions in Taiwan face and the level of impact caused by each type of risk, the study also investigates the relation among factors that affect the risk in financial institutions. The outcome of analysis reveals organizational culture, risk appetite, and internal audit as the most important factors affecting the vulnerability in financial institutions. The study provides a more solid risk evaluation mechanism and recommendation for the management of financial institutions as well as expand new field for financial research, enriching the new horizon for financial risk evaluation.**

**Keywords:** Risk management, Fuzzy Cognitive Map, Vulnerability, Resilience

## INTRODUCTION

What is risk? In short, risk refers to uncertainty and the change of expectation value caused by it. The outcome of a certain event or a certain business operation is usually uncertain, and it is always difficult to estimate and evaluate its profits or losses precisely in advance. The change caused by the uncertainty is the risk. Sometimes, risk emphasizes the volatility or uncertainty; that is, the expected losses of uncertain events are based on the level of deviation in expectation value. With internationalization and globalization, the rapid change of the era, and the increase in the diversification of customer demands, business management is facing intensive turbulence. Currently, the financial industry in Taiwan is in the era of radical changes at the external environment and fast revolution in information technology. It forces the operators in the financial industry to equip themselves with certain knowledge and responding capability for the business risk at the external environment in order to be ready to provide a situation-conforming and concrete revolutionary proposal for the financial crisis encountered. The dealers in the financial industry must draft the risk identification for the surrounding environment, set up fitting business strategies according to different types of risk, and plan specific practices for the potential risk scenarios that the organization might face in order to reduce impact effectively when the company faces risk as well as ensure the maintenance of competitive advantages. That is to say, the critical issue for managers in financial institutions is to find out the approach of constructing risk map by identifying the financial risk when dealing with the change of business environment and the competitive market.

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specific practices for the potential risk scenarios that the organization might face in order to reduce impact effectively when the company faces risk as well as ensure the maintenance of competitive advantages. That is to say, the critical issue for managers in financial institutions is to find out the approach of constructing risk map by identifying the financial risk when dealing with the change of business environment and the competitive market.

The purpose of the study is to use financial institutions as the research object to explore the factors affecting the risk in financial institutions and the structural relation among the factors. Other than quantitative variables, the system variables in the study are also with qualitative characteristics and the cause-effect relation among the system variables will not be able to be expressed with definite quantitative equation. Thus, the study uses fuzzy cognitive maps (FCM) to establish factors that affect risk management in financial institution and the structural relation among the factors. Based on the characteristics of fuzzy cognitive map application, the fuzzy relation of variables built up by the members in financial institutions in the sensitivity model is used for system input. By the operation of fuzzy cognitive maps, the cause-effect relation among variables in the system is analyzed as well as the changes of variable status under the impact of fuzzy relation in the system are investigated. During the construction of FCM, its analysis results in different circumstances are specially discussed through scenario analysis. It is anticipated the business decisions required by the research object can be drawn up more objectively.

## LITERATURE REVIEW

The concept of vulnerability was first applied to the field of natural science, and the scholars who are engaged with natural disaster were discussing the relation between vulnerability and environmental change. Since the concept of vulnerability was proposed for the first time, it has been widely applied in the field of natural science, such as ecology and disaster science, as well as in the field of social science, such as sociology and economics. As a result, vulnerability represents different meanings in different fields. Sheffi et al.（2006）defined the vulnerability as an individual's or group's prediction, handling, resistance, and recovery capability towards the impact of the disaster. Bianchi et al.（2017） defined the vulnerability as the sensitivity towards the losses and destruction caused by the disaster from groups or organizations while Wang（2014）believed vulnerability contains exposure and coping capacity. Here, the exposure refers to the risk of disaster events and the coping capacity includes the ability of being able to bear the impact and to continue the operation as well as the ability of being able to recover after the disaster.

The concept of resilience was expanded to ecology by Holling in 1973 and resilience was defined as the system's capability of returning back to a balanced state after being disturbed. The concept related to resilience was also applied to the psychology and it was developed from the perspective of crisis responding to discuss invulnerability, good adaption, and stress resistance; these are the key concepts of resilience development in psychology. Since the resilience was developed, its concept has been widely applied to the process related to the interaction between the individual and the environment. Sheffi（2005）defined resilience with the idea of system recovery and becoming stable and highlighted it is the capability to return the system back to the original state after the turbulence. Turner（2003）extended resilience to climate change and link vulnerability to the resilience. Comfort also applied resilience to the earthquake disaster and responding behavior after the disaster in 1999 and believed resilience is the ability to use current resources and skills for new environment adaptation. Buckle et al.（2001）defined resilience as the ability of resisting losses or potential losses by groups or organizations as well as the recovery after the destruction.

 

According to the analytical results of literature review above, vulnerability towards interference can be seen as the possibility of damage and potential seriousness to companies. Besides, companies must understand the following three points when evaluating the vulnerability: 1. What might go wrong? 2. How likely it might happen? 3. What is the consequence when it happens? Interference can be classified as the following three types: Natural Disasters – belonging to incidents occurring randomly and the actual incidents can be used for data analysis in order to predict its probability; Accidents – belonging the involuntary negligence and historical data can be used to predict the probability; Intentional Disruptions – it refers to the loss caused by purposeful intention and it is difficult to predict the probability. Decision makers usually have to handle problems with multiple attributes and the relation among the attributes might be conflicted or with correlation. How to solve the complicated decision-making problems is one of the challenging issues among many strategic methods. Recently, research on the complex social and economic problems done by fuzzy cognitive maps with quantitative mathematical analysis has also received a lot of precious outcome. The method uses the principles of system analysis and decision-making system while coordinating with information feedback and delay in the system to reflect actual operation situation through simulation as the accordance of strategy modification and proposal evaluation.

## DATA COLLECTION AND ANALYSIS

In the past few years, risk management has started to focus on the issues of vulnerability and resilience as well as introduced the two factors into the depth of risk management. In order to understand the relevant management factors and impact factors when the research object faces financial crisis, the study uses vulnerability and resilience and find out 15 items of vulnerability factors that affect financial crisis via literature review and consolidation, expert interview, and the researcher's personal experience and observation; Relevant vulnerability factors and content description is arranged and shown on Table 1. Table 1 reveals the 15 factors that affects the vulnerability of financial institutions include "risk appetite", "compliance", "operational management", "organizational culture", "internal audit", "frequency communication & negotiation", "external linkage", "financial risk", "vulnerability", "system resilience", "adaptability to changes", "global economic prosperity", "government policy", "business conditions", "market confidence", and "product performance".

Table 1 shows the numerical meaning for each variable in the fuzzy cognitive maps, and the state value of each variable is presented as 0∼1. Take frequency of communication & negotiation as an example, if the numerical value is closer to 1, it represents the higher frequency of communication & negotiation in the financial institution.

**Table 1 Description of vulnerability for the research object**

| Variable | Description of content |
|---|---|
| Risk appetite | Risk appetite refers to the attitude when a company faces financial risk; the rise of risk appetite means that the financial institution is willing to take higher risk in order to fight for a higher return. |
| Compliance | It refers to the level of compliance and respect towards to relevant financial legal regulations that a financial company holds. If a company can follow the legal regulations well, it is possible that the company can reduce the risk related to law. However, it might also cause the company's rigidness and inflexibility in terms of decision making. |
| Operational management | It refers to the professionalism and consistency of employees' performance during the daily operation in the company. If the performance of operational management is poor, the possibility of operational risk caused by human error is higher. |
| Organizational culture | Organizational culture is the sum of the highest value standard, basic belief, and code of conduct created and owned by the organization during the long-term survival and development, and it is followed by most of the members in the organization. Good organizational culture contributes to the operational performance and capability of resisting the risk of a company. |
| Internal audit | The sound and perfect internal audit of the financial institution will help the institution achieve better operational management as well as reduce errors and further financial risk caused by human management and operational procedures. |
| Communication & negotiation frequency | It refers to the frequency of meeting and negotiation for daily operation among members in the financial institution. When encountering problems in operation or emergency condition, the frequency of communication, meeting and negotiation will increase. |
| External linkage | The linkage between financial institutions and external environment includes the linkage between the government and other relevant industries or companies. The higher the external linkage is, the better the possibility of being flexible or controlling the information of tiny changes in the market is. Therefore, it can strengthen the level of resistance when a financial institution faces the risk. |
| Vulnerability | The vulnerability of the financial institution refers to the pre-existing status that is in the system before the disaster, and it belongs to the structural factor to the impact when a financial system encounters the disaster. |
| System resilience | It refers to the time and capability needed for recovering from abnormality to the normal when the system is impacted by external force. System resilience will be affected by factor $X_{10}$~$X_{15}$. |
| Adaptability to changes | It refers to the emergency responding ability from the members when some link of the system malfunctions. |
| Global economic prosperity | The members comprising the financial ecological chain are almost without borders. Therefore, many financial crises and risks are relevant to global financial ecological chains. The global economic prosperity will directly or indirectly affect the resilience of a financial institution. |
| Government policy | Government's handling ability, policy making, and implementation capability after the financial crisis will affect the recovering ability of the financial institution. |

 

| | |
|---|---|
| Business conditions | It refers to the level of impact on the industries related to financial institutions after the market environment goes through the financial crisis. If the business conditions become worse due to the impact, it will carry negative influence to the resilience of the financial institution. |
| Market confidence | Market confidence refers to the confidence of the whole market towards the whole economic environment after the market encounters financial crisis or the company experiences financial disaster, including prosperity, government, and industry. |
| Product performance | It refers to the competitiveness and performance on the product and the service in a financial company. If the product is with better performance in the financial company, it will have more chances to recover in a faster speed after the company encounters the impact of the risk. |

Figure 1 is the complete fuzzy cognitive maps containing two variables of vulnerability and resilience. There are 15 variables in total with subtotal 76 pairs of relation combination, including the complete relation of risk vulnerability and resilience in financial institutions. Figure 1 reveals the 15 factors that affects the vulnerability and resilience of financial institutions include risk appetite, compliance, operational management, organizational culture, internal audit, frequency of communication & negotiation, external linkage, vulnerability, system resilience, adaptability to changes, global economic prosperity, government policy, business conditions, market confidence, and product performance.

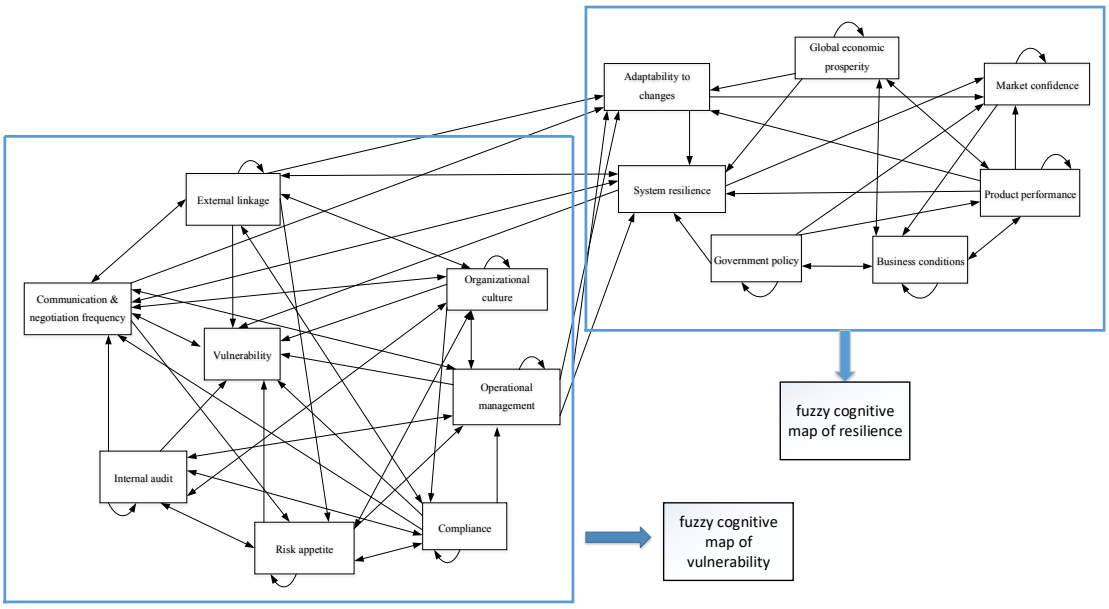


**Figure 1 Complete fuzzy cognitive maps for risk management in financial institutions**

The fuzzy cognitive maps showing on Figure 1 was obtained after expert interview and analysis. Next, a second expert questionnaire was to be carried out. In the beginning, the respondents were briefed the research scope and purpose and explained the definition and content of each variable. After confirming the definition and content of the 15 affecting factors, it then moved to the responding procedure. Experts were asked to evaluate the state value of the 15 factors and fill out the state of the variable in the questionnaire format provided in the study as well as the power weights between the variable and other variables. The state value of the variable is limited to the rational between 0 and 1 with more than two decimal places while the power weights between variables is limited to the rational between -1 and 1 with more than two decimal places according to the fuzzy cognitive maps. After collecting data from the

experts, geometric mean is used to consolidate the outcome of variable state value provided by each expert due to the roles and functions of the service system in financial institutions that each expert belongs to or familiar with are different. In order not to be affected by the extreme value, the power weights between variables also use geometric mean to consolidate the outcome from experts' response.

Table 2, Table 3 and Table 4 respectively present the weights matrix affecting vulnerability in financial institutions and state value between each variable, the weights matrix affecting resilience in financial institutions and state value between each variable, and the variable weights affecting risk management in financial institutions. The numerical numbers in these matrices are the outcome from the 9 expert questionnaires with all data presented by geometric means, including weights between two variables and the initial state value of each variable. In terms of weights, positive value represents positive correlation while negative value represents negative correlation. For example, the value for $X_1 \rightarrow X_2$ is -0.3 and it means $X_1$ has negative impact on $X_2$ with an impact level of 0.3 while the value for $X_2 \rightarrow X_6$ is 0.26 and it means $X_2$ has positive impact on $X_6$ with an impact level of 0.26.

**Table 2 Weights matrix affecting vulnerability in financial institutions and state value between each variable**

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | Stage |
|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | 0.65 | -0.3 | -0.3 | 0.1 | -0.4 | 0 | 0 | -0.5 | **0.65** |
| $X_2$ | -0.5 | 0.85 | 0.3 | 0 | 0.1 | 0.26 | -0.74 | 0.4 | **0.55** |
| $X_3$ | 0 | 0 | 0.35 | -0.2 | 0.27 | -0.3 | 0 | 0.3 | **0.60** |
| $X_4$ | 0.1 | 0.2 | 0.2 | 0.85 | -0.3 | -0.53 | 0.5 | -0.73 | **0.45** |
| $X_5$ | -0.3 | 0.3 | 0.4 | -0.2 | 0.15 | 0.5 | 0 | -0.2 | **0.40** |
| $X_6$ | 0.24 | 0 | 0.2 | 0.3 | 0 | 0 | 0.5 | -0.5 | **0.30** |
| $X_7$ | 0.2 | -0.23 | 0 | -0.3 | 0 | 0.1 | 0.3 | -0.74 | **0.33** |
| $X_8$ | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 | 0 | **0.60** |

**Table 3 Weights matrix affecting resilience in financial institutions and state value between each variable**

| | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $X_{14}$ | $X_{15}$ | Stage |
|---|---|---|---|---|---|---|---|---|
| $X_9$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | **0.60** |
| $X_{10}$ | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | **0.50** |
| $X_{11}$ | 0.20 | -0.10 | 0.80 | 0.00 | -0.40 | -0.60 | 0.00 | **0.50** |
| $X_{12}$ | 0.20 | 0.00 | 0.00 | 0.20 | -0.20 | 0.30 | 0.00 | **0.45** |
| $X_{13}$ | -0.20 | -0.20 | -0.20 | 0.00 | 0.50 | -0.45 | -0.15 | **0.45** |
| $X_{14}$ | 0.00 | 0.00 | 0.20 | -0.10 | -0.30 | 0.60 | -0.10 | **0.50** |
| $X_{15}$ | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.50 | **0.70** |

 

**Table 4 Variable weights in the complete matrix affecting risk management in financial institutions**

| | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $X_{14}$ | $X_{15}$ | Stage |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $X_1$ | 0.65 | -0.3 | -0.3 | 0.1 | -0.4 | 0 | 0 | -0.5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.50** |
| $X_2$ | -0.5 | 0.85 | 0.3 | 0 | 0.1 | 0.26 | -0.74 | 0.4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.55** |
| $X_3$ | 0 | 0 | 0.35 | -0.2 | 0.27 | -0.3 | 0 | 0.3 | 0.25 | 0.50 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.60** |
| $X_4$ | 0.1 | 0.2 | 0.2 | 0.85 | -0.3 | -0.53 | 0.5 | -0.73 | 0.00 | 0.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.45** |
| $X_5$ | -0.3 | 0.3 | 0.4 | -0.2 | 0.15 | 0.5 | 0 | -0.2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.40** |
| $X_6$ | 0.24 | 0 | 0.2 | 0.3 | 0 | 0 | 0.5 | -0.5 | 0.20 | 0.30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.30** |
| $X_7$ | 0.2 | -0.23 | 0 | -0.3 | 0 | 0.1 | 0.3 | -0.74 | 0.15 | 0.35 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.33** |
| $X_8$ | 0 | 0 | 0 | 0 | 0 | 0.7 | 0 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.60** |
| $X_9$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **0.60** |
| $X_{10}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 | **0.50** |
| $X_{11}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | -0.10 | 0.80 | 0.00 | -0.40 | -0.60 | 0.00 | **0.50** |
| $X_{12}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.20 | -0.20 | 0.30 | 0.00 | **0.45** |
| $X_{13}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | -0.20 | -0.20 | -0.20 | 0.00 | 0.50 | -0.45 | -0.15 | **0.45** |
| $X_{14}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | -0.10 | -0.30 | 0.60 | -0.10 | **0.50** |
| $X_{15}$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.50 | **0.70** |

With the weights matrix between variables and state value of each variable in fuzzy cognitive maps, arithmetic operation based on the fuzzy cognitive maps can be carried out to explain the operational status of the system. The calculation formula for fuzzy cognitive maps is shown as Formula (1) below:

$$x_i(t) = f \cdot \left(\sum_{\substack{j=1 \\ j \neq i}}^{n} x_j(t-1) w_{ji}\right), f = \frac{1}{1+e^{-\lambda x}} \qquad (1)$$

In Formula (1), $x_i(t)$ refers to the state of variable *i* in the phase *t* and its value is between 0 and 1. If variable $x_i$ is closer to 1, it means the state of variable $x_i$ is better (or worse depending on the definition of the variable). $w_{ji}$ is the weight of variable *j* affecting variable *i* and the absolute value of $w_{ji}$ is smaller than 1. Positive value represents variable *j* has positive impact on variable *i* while negative value represents variable *j* has negative impact on variable *i*; the higher value represents higher impact level. According to Formula (4), it reveals the state of variable $X_i$ in the phase *t*+1 is determined by the state of all variables affecting variable $X_i$ in phase *t*.

*f* is a transition function and its purpose is to ensure the variable can be converged in the scope of initial setup after repeated arithmetic operation of the values in fuzzy cognitive maps; that is, converging the value of $x_i(t)$ into value between 0 and 1 after calculation. The study uses logistic signal function as the transition function and the common setting of its parameter λ is between 0.2 and 5; besides, the setup of λ is related to the quantity of variables in the fuzzy cognitive maps and the level of complexity between variables. Researchers can set up λ value according to the characteristics built up for the fuzzy cognitive maps. After referring to

relevant literatures, the study sets up λ value as 3. Figure 2 explains the logistic signal function when the value of λ is 3.

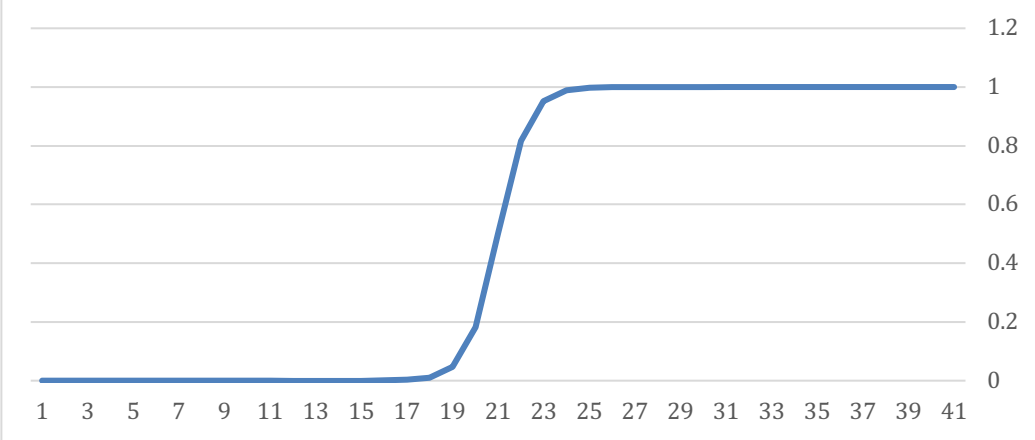


**Figure 2 Logistic Signal Function (λ=3)**

Based on the initial values of state variables and power weights matrix among variables, the arithmetic operation according to the procedures shown on Formula (1) is repeated executed to obtain the dynamic changes of between each variable in the system at any time. According to the experts interviewed, international financial institutions require around one week for preparation and actual effect on the change when the system encounters external changes and needs to be modified. The lead time of the one week involves with the aspects of (1) confirming the content of operation that needs to be modified through meetings, (2) adjustment in the operational dimension at each relevant unit, and (3) issuing the new instruction to each unit and start the implementation of new operation. In addition, Wang et. al. (2010) also set the managerial implications for the repeated arithmetic operation in fuzzy cognitive maps as one week during the research related to the operation of financial institutions. Therefore, the study sets up the managerial implications for the repeated arithmetic operation as one week with the reference to the suggestions from the interviewed experts and literature review. Figure 3 and Figure 4 demonstrate the dynamic change with the consideration only on variables of system vulnerability and resilience, and the final state of state variable respectively.

If only considering the vulnerability in financial institutions, the result of dynamic analysis of fuzzy cognitive maps is as shown on Figure 3. The dynamic changes of variables $X_1$~$X_8$ is explained on Figure 8, and most of the variables in the fuzzy cognitive maps have achieved a steady result after the repeated arithmetic operation for eight times. All variables almost achieved stability at the 10$^{th}$ arithmetic operation, and it reveals the cycle of risk management in the financial institution takes around 2-2.5 months before reaching a relative stable outcome. It can be found in Figure 8 that "frequency of communication & negotiation ($X_6$)" increases from the initial value 0.3 set up in the beginning to the value of 0.57 while "vulnerability ($X_8$)" reduces from the initial value 0.6 set up in the beginning to the value of 0.34.

 

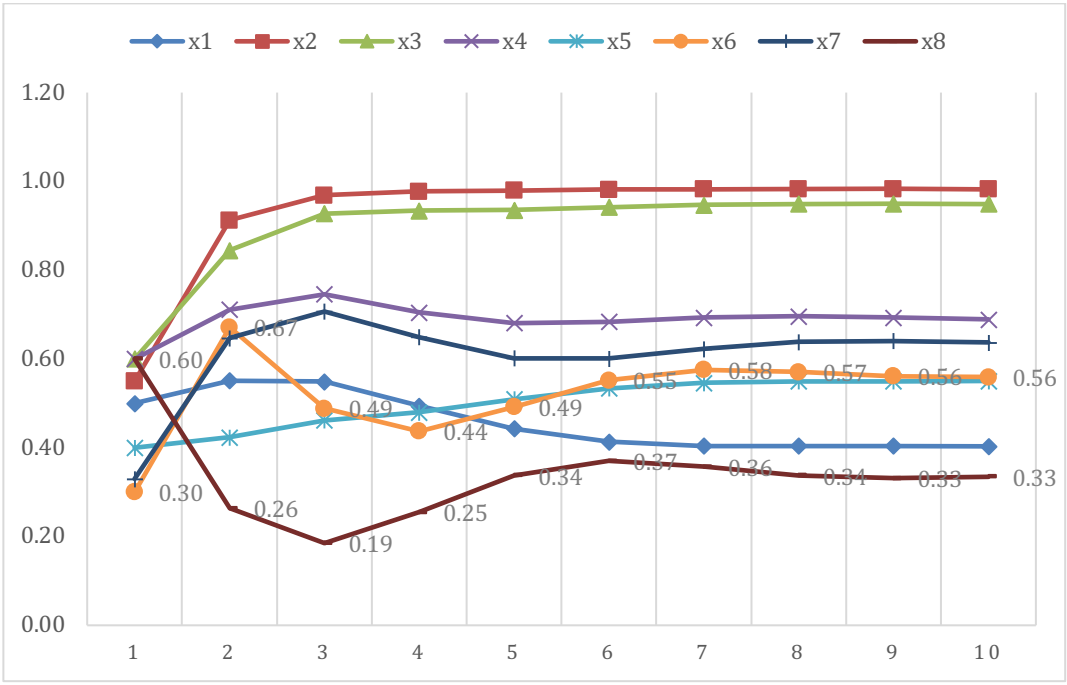


**Figure 3 System dynamic change diagram in fuzzy cognitive maps for variables $X_1$~$X_8$**

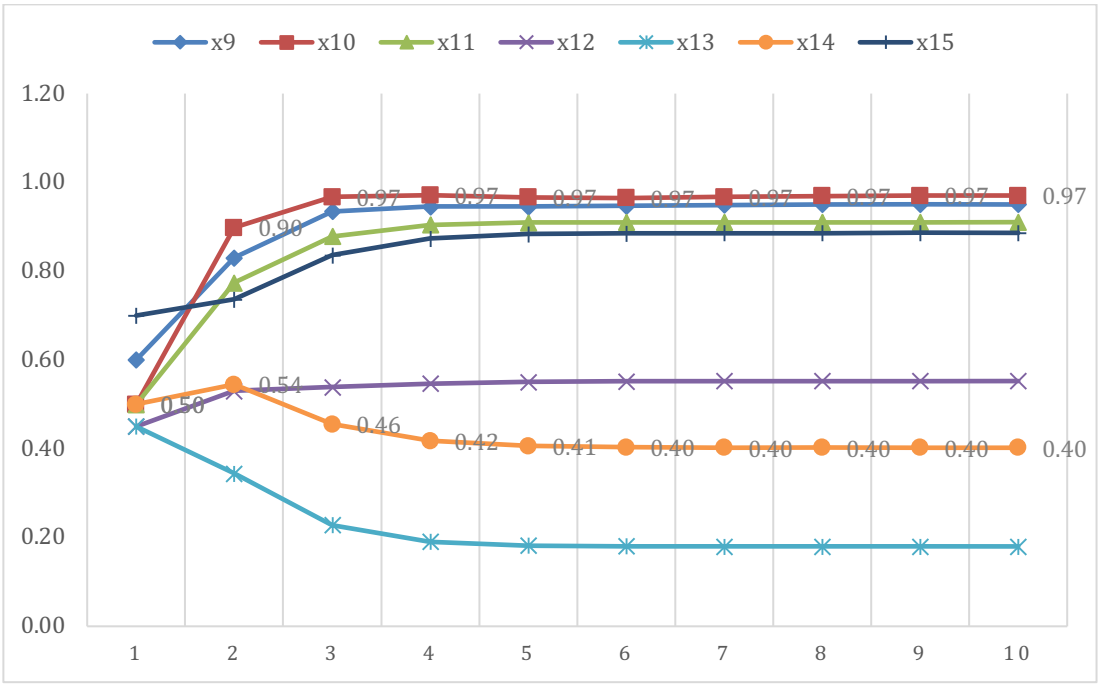


**Figure 4 System dynamic change diagram in fuzzy cognitive maps for variables $X_9$~$X_{15}$**

Figure 4 explains the dynamic changes among variables $X_9$~$X_{15}$, and it is the analysis on the changes in the external environment. As the result, only variables of resilience, adaptability to changes, global economic prosperity, government policy, business conditions, market confidence, and product performance are considered. Figure 4 reveals most of the variables in the fuzzy cognitive maps have achieved a stable outcome after the repeated arithmetic operation for eight times, and it shows it takes around 2 months to achieve stability. According to the analytical result, "adaptability to changes ($X_{10}$)" increases from the initial value 0.5 set up in the beginning to the value of 0.97 while "market confidence ($X_{14}$)" reduces from the initial value 0.5 set up in the beginning to the value of 0. 4.

Figure 5 shows the dynamic changes among variables $X_1$~$X_{15}$ and it is the complete fuzzy cognitive maps with the consideration of both vulnerability and resilience. It reveals the variables in the fuzzy cognitive maps have mostly achieved a steady outcome after the repeated arithmetic operation for eight times. It means each member in the financial institution can all for comprehensive meetings for problem shooting when there is any problem on the service provided. From the dynamic change diagram, it demonstrates it take around 2 months for the service system in financial institutions reaching stability.

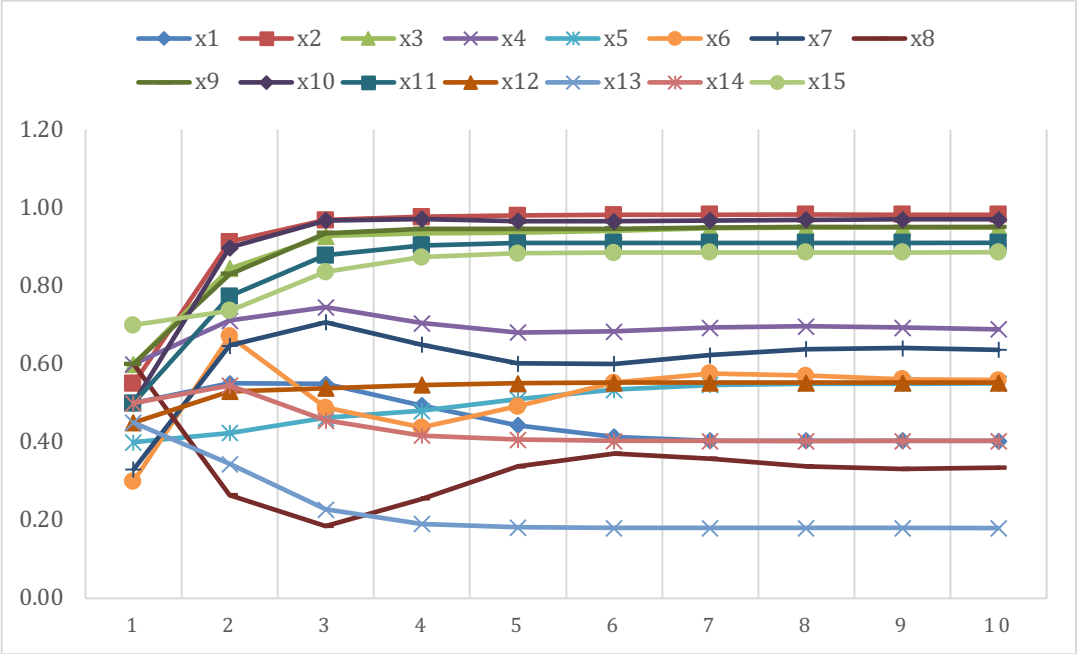


**Figure 10 System dynamic change diagram in the complete fuzzy cognitive maps**

Table 5 demonstrates the initial state value of each variable and the state value after stabilization. Table 11 reveals the initial value of "risk appetite ($X_1$)" is 0.65 and it achieves the stable value of 0.51 after arithmetic operation. The decrease of risk appetite after adjustments means institutions turn to be more carefully in terms of risk acceptance. Moreover, the variable of "internal audit ($X_5$)" increases to the stable value of 0.55 from the initial value of 0.4 after arithmetic operation. The increase of internal audit after adjustments shows the force of auditing is strengthened.

**Table 5 Initial state value of each variable and state value after stabilization**

| $X_i$ | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ |
|---|---|---|---|---|---|---|---|---|
| Initial value | 0.65 | 0.55 | 0.60 | 0.45 | 0.40 | 0.30 | 0.33 | 0.60 |
| Stable value | 0.51 | 0.98 | 0.95 | 0.69 | 0.55 | 0.57 | 0.64 | 0.34 |
| $X_i$ | $X_9$ | $X_{10}$ | $X_{11}$ | $X_{12}$ | $X_{13}$ | $X_{14}$ | $X_{15}$ | |
| Initial value | 0.60 | 0.50 | 0.50 | 0.45 | 0.45 | 0.50 | 0.70 | |
| Stable value | 0.95 | 0.97 | 0.91 | 0.55 | 0.18 | 0.40 | 0.89 | |

## CONCLUSION AND RECOMMENDATION

In recent years, the phenomena caused by the argument of using new scientific model to explain and explore the "co-evolution between business and environment" have become the

topics concerned by many scholars. Many researches demonstrated the premise of revolution with learning and open attitudes is existed when the enterprise is exposed to the risk and disaster. Under the confusing and uncertain environment, companies will implement the behaviors of organizational transformation and adaptation based on the mechanism of cooperative competition and co-revolution.

The study uses business risk in financial institutions as the research topic and fuzzy cognitive maps are constructed based on the perspective of vulnerability and resilience. The factors affecting vulnerability include risk appetite, compliance, operational management, organizational culture, internal audit, frequency of communication & negotiation, and external linkage. According to the construction of fuzzy cognitive maps and the result of dynamic analysis, "organizational culture", "compliance", and "risk appetite" are the main factors affecting the vulnerability in financial institutions. If the competent authority of financial institutions can request financial institutions to comply with relevant financial regulations as well as review the organizational culture in the financial institution and its risk appetite, the issues of managing risk faced by financial institutions will be effectively achieved. Moreover, it will also reduce the vulnerability of the financial institution. The study proposes the following four strategies for risk management to the managers in financial institutions:

- Strategy 1: Risk aversion- It is trying to avoid a certain loss and do not take any unnecessary burden and the risk that is not unbearable.
- Strategy 2: Risk elimination- Take initiative to deal with risk as well as try to control the scope and intensity of the loss caused by the risk at the same time. The approaches used include "risk adaptation" (carrying out continuous investigation and prediction on risk environment with courage and insight), "risk aversion" (prevent, separate, reduce, and improve obstacle caused by the risk), "risk offset" (using portfolio or trading behavior to neutralize or balance), and "risk rescue" (adopting responding measures to reduce the intensity of loss, change property and direction, minimize the scope, and cut off chain reaction).
- Strategy 3: Risk sharing- Break down and transfer big risk that is not able to be avoided or eliminated to other enterprises or the third party beyond the insurance company by measures or shifting. The approaches include "risk selling" (via sale and purchase contract), "risk contracting" (contracting, outsourcing and global purchasing inviting contract), "risk exemption" (exempt assignor's loss by exemption agreement), "risk guarantee" (deposit funds to the guarantee unit to exempt the loss in the said scope of guarantee), and "risk diversification" (transfer the risk to local branch office or different operational and sales units by dividing and sharing- "business diversification and multi-channel selling").
- Strategy 4: Risk control- A strategy for taking the risk by the enterprise itself through risk identification, risk analysis, and risk control system. The approaches include "self-insurance" (during the business implementation or in the beginning of the project, allocate part of capital as hedge funds and loan funds according company's financial status, losses in the past few years, and insurance premiums), and "joint captive insurance" (establish captive insurance company or insurance fund with the industry trade association or society for non-commercial mutual insurance).

Due to the operational goal for financial institutions usually reflects stockholders' equity and the greatest profits for the directors in enterprise, the most important topic for risk management in financial institutions is that management team must be able to identify the risk points related to business strategy and evaluate the possible impact in order to plan and control the target. In the past few years, the business width and depth in financial institutions continue expanding and systems in the bank are complicated and intertwined, but the number

of supervisors in the financial industry in Taiwan does not relatively increase. On the other hand, central data warehousing system has not been established in Taiwan and it is unfavorable for the fulfillment of benefit integration in cross-sector supervision. The current situation of the financial industry explains the importance of establishing an efficient mechanism for risk management in financial institutions.

With the development and mature of artificial intelligence, AI is definitely affect different industries and it is not exception in banking institutions. Therefore, it is suggested that researchers in subsequent study can focus on AI technology to construct the risk management issues that banking institutions might face along with the development of AI, including the impact analysis of AI customer service and AI banking service towards customers, employees as well as product pattern and service approach in the bank. In addition, in terms of research methods, it is always assumed the influence coefficient between two variables is fixed when conducting arithmetic operation in fuzzy cognitive maps in the past. During the process of analysis for the study, it is found that it is necessary to set up mutual power weight for some variables and then adjust the value according to the result of each repeated arithmetic operation. As a result, it is recommended researchers in the future can set up the influence coefficient as functional relation that is with certain logic in order to improve the potential error existed during arithmetic operation in fuzzy cognitive maps.

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