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IMPROVING CHINA'S REGIONAL FINANCIAL CENTER MODERNIZATION DEVELOPMENT USING A NEW HYBRID MADM MODEL

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Abstract. The regional financial center is the propeller of regional economic development. Regional financial center modernization, however, has been the predominant propulsion of economic sustainability. Decisions related to regional financial center modernization development are inherent problems of multiple attribute decision-making (MADM), and strategically important to the government. The purpose of this paper is to set up a regional financial center improvement model for modernization development, as based on a hybrid MADM model, which addresses the main causal-effect factors and amended priorities in order to strengthen ongoing planning. This paper adopts a new hybrid MADM model combined with the DEMATEL technique to construct an influential network relationship map (INRM) and determined the influential weights of DANP. Then, a modified VIKOR method using influential weights is applied to measure and integrate the performance gaps from each criterion into dimensions, as well as the overall criterion for evaluating and improving the modernization development of the regional financial center, as based on INRM. Finally an empirical case study using data from the Guangzhou regional financial center is carried out as an example to demonstrate the suitability of the proposed hybrid MADM model for solving real-world problems. The results show the priorities for improvement, as based on the degree of the effect and impact of the dimensions, as follows: first is making "government policy", second is enforcing "financial infrastructure and safety", next is formulating "financial institutions and human resources", and finally "financial service".

Keywords: regional financial center, modernization development, improvement model, MADM (multiple attribute decision making), DEMATEL, INRM (influential network relation map), DANP (DEMATEL-based ANP), VIKOR.

JEL Classification: O160, O180, O380, R110, H110.

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Introduction

While regional economic development is the propeller of national economic growth, the regional financial center has been the central pillar of regional economic development. It clusters many financial institutions into a specific area to form a financial trading platform, and plays the role of an international financial bridge. A regional financial center offers comprehensive financial services to promote capital assemblage and accelerate financial depth and innovation, in order to enhance the country's economic strength. Luintel *et al.* (2008) found that financial structure and financial development significantly affect the output level of most countries. It is necessary to create a geography agglomeration of financial activities due to information problems, and a financial center could be its platform (Zhao *et al.* 2004). Cobb (1998) provided evidence that the global major financial centers, such as New York, London, and Tokyo, have good financial services. In spite of the representative international financial center, New York and other regional financial centers, which are established in the East, Central, and West in the US, including Washington, Chicago, Boston, Houston, Luoxia, and San Francisco, promote local economic operational quality and efficiency.

Whether an international financial center or a regional financial center, both are useful information exchange platforms, and can decrease information asymmetries and financing costs (De las Mercedes Adamuz, Cortés 2015); thereby increasing financial transactions and services (An *et al.* 2015). The changes of major global events, such as China's shift to a market economy and the founding of a single-market region in Europe, as well as a high degree of financial connectedness under globalization (Gao *et al.* 2015), have stimulated the growth of financial centers, and promoted the development of several new locations and the provision of more financial transactions and services to attract international business (Cetorelli, Peristiani 2013). Al-Salem and Mohammed (2012) indicated that an international financial center plays a dominant role in providing multi-financial services and agglomeration of financial institutions, which are competitive in global financial markets. When a dominant country is also a global financial center, it would expand the improvement of social welfare (Yu 2015). Farooq and El Ouadrhiri (2014) suggested that firms headquartered in a financial center have well-functioning information environments (Miller 2015) than other firms, via the clustering of firms, and significantly outperform dispersed firms during the crisis period. Jarvis (2011) claimed that the establishment of a financial center can support financial sector growth and maintain their competitiveness in emerging markets.

Regional financial centers depend on the major regional city, and are formed by financial factors and resources to assemble in a central city. In addition to providing economies of scale and speeding up self-growth, they also emerge as a strong radiative effect on neighbourhoods and provide innovative financial features. Hoening (1998) argued that the world of finance has changed dramatically, with banks' credit markets and payment system requirements through a network; thus, a secure internet implies financial modernization. Leach (2000) pointed out that financial service companies use new technologies to provide the best service to households and enterprises, and have financial regulatory reforms in alignment with financial institution modernization (Khan 1999).

A comprehensive survey of the relative issues when discussing international/regional financial center modernization development by influential analysis mostly applied narrative presentations. Few studies adopted qualitative data, and some financial center modernization variables lack quantitative data available to experts with practical experience. Therefore, in order to fill the gap in literature for improving financial center modernization, and to promote the effectiveness and validity, this paper considers all related variables of the factors of regional financial center modernization development, as based on the empirical case of Guangzhou in China. This research focuses on the methods required to improve regional financial center modernization, thereby, stimulating regional economic development, and considering the existing/occurring inter-relationship problems among multiple criteria/attributes for decision-making in realistic situations (Tzeng, Huang 2011, 2013; Liou, Tzeng 2012; Peng, Tzeng 2013). In recent years, several important new concepts and trends of the hybrid MADM (multiple attribute decision making) model for solving actual problems are considered. MADM is able to simultaneously consider multiple criteria/attributes, which help decision makers evaluate and estimate the best case, as based on the characteristics of a limited number of alternative cases, for application in ranking and selection (traditional approach), as well as for building performance improvement strategies (new approach), such as solving the three major problems of this research. First, the traditional MADM methods assumes the criteria/attributes are independently, linearly, and hierarchically structured; however, in reality, problems are often characterized by interdependent criteria/attributes, and may even show feedback-like effects for avoiding "some statistics and economics are unrealistic in the real world", such as, assumptions/hypotheses, etc.; second, relatively good solutions according to the max-min concept of existing alternatives are replaced by "aspiration levels" to satisfy contemporary social needs, and avoiding "picking the best apple among a barrel of rotten apples" (Simon incorporated the basic concept of the "aspiration level" in his work, and received the Nobel Prize in Economics in 1978); third, emphasis in the field has shifted from ranking/selection when determining the most preferable approaches to performance improvement of existing methods by systematics, as "we need a systematic approach to problem-solving; instead of addressing the systems of the problem, we need to identify the sources of the problem" for avoiding "stop-gap piecemeal" (Liou, Tzeng 2012; Liou 2013; Peng, Tzeng 2013). Thus, this paper seeks a hybrid multiple attribute decision-making (MADM) model combining the decision-making trial and evaluation laboratory (DEMATEL) technique to construct a total influence-relation matrix by dimensions and criteria for constructing an influential network relation map (INRM) to solve real-world problems using natural language to identify the degree of effects from the different dimensions/criteria. Then, the basic concept of the analytic network of process (ANP) was used to determine the influential weights of DEMATEL-based ANP (DANP) by using the total influence relation matrix of DEMATEL. Finally, the modified VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) method, using the influential weights of DANP as integration-weighting, was used to assess and improve the performance gaps. In addition to being used for ranking and selection, it could also be used for providing innovating/creating regional financial center modernization improvement strategies, as based on INRM, to reduce the gaps near to zero in each dimension and criterion, and then, for promoting efficiency and satisfying social needs in regional financial services.

The remainder of this paper is organized, as follows. Section 1 briefly introduces the assessed dimensions and criteria in related literature; Section 2 discusses the analytical framework and methods for constructing a regional financial center modernization evaluation system; Section 3 proposes an empirical case of an improvement plan for Guangzhou regional financial center modernization; Section 4 offers conclusions.

1. Related literature

During this era of globalization, information technology, and market-orientation, finance has been at the core of modern economies. Countries and firms with higher levels of financial market development have more external finance and growth opportunities, which benefit economic development (Fase, Abma 2003; Bena, Ondko 2012). Boehne (2000) indicated that a well-functioning financial system is the robust core of a strong economy, and consumer confidence is the underpinning of a successful financial system. Over the last two decades, the Chinese government has guided rapid modernization and transformation of its banking system, and increased its power on the global stage (Rana 2012). When building a modern regional financial center, sound software and hardware are indispensable. The many kinds of variables related to regional financial center modernization can be grouped into four categories.

1.1. Government policy

A financial incentive system has been recommended as the means of foreign direct investment (FDI) inducement, and balances regional economic development in reaction to the demands of local governments. If government supports the goals of the firms and customizes their FDI incentives, they will attract much more foreign capital (Lim 2005). Deng *et al.* (2012) claimed that tax incentives have been utilized worldwide to attract FDI; however, the productivity spill over effects of FDI can elevate GDP, national output, and welfare. Special tax incentive zones in China implemented concessionary tax rates and incentives, which are effective in attracting FDI (Tung, Cho 2000). In order to attract or retain businesses, many American communities provide tax abatements or tax credits to enterprises, particularly lower-income communities; however, state governments also face a trade-off between business and tax revenue (Felix, Hines Jr. 2013). Thakor (2012) showed that financial innovation incentives and increasing the amount of innovation generate profit based on innovation loans, which help to lower entry costs. In addition, the greater the transparency of the balance sheets of financial institutions, the less effect from financial crisis on innovation and the less loan-related profit for banks. Gertler *et al.* (2012) indicated that a government credit policy during a crisis affects the exposure of the financial system.

Financial regulations should not only focus on the bank sector, but also monitor the development of stock markets, especially in emerging markets. Emerging markets mainly use bank-based financial systems, and are not market-based, which requires more time to recover from economic downturns after a financial crisis (Baum *et al.* 2011; Allen *et al.* 2012). Since the late 1980s, there have been structural changes, as well as the openness of domestic financial markets in emerging economies. Higher credit and equity market integration decrease the cost of capital, and reflect the economic benefits brought by financial

integration. Enterprises enjoy the positive outcomes of financial integration, which are lower monitoring costs, more transparent information, and better creditor and shareholder protection (Lucey, Zhang 2011). However, while the openness of financial markets contribute to the development of financial centers, in the face of financial instability in the international environment, financial supervision and regulation are increasingly important. Klomp and Haan (2012) used 200 banks from 21 OECD countries, and found that supervisory control, capital regulations, and market entry regulations all exert significant impacts on capital and asset risk; and banking norms and supervision of each country differ in regard to banking risks. Buck and Schliephake (2013) also posited that minimum capital requirements and the supervision of domestic banks involve a trade-off: higher capital requirements decrease banks' profitability. Strict supervision causes a reduction in banks' vulnerability to collapse, thus, it is essential that supervision is in line with international standards and harmonizing regulations. Barth *et al.* (2013) clarified that banking regulations, supervision, and market monitoring have significant effect on bank efficiency, implying that there is a potential trade-off between bank safety and efficiency, and that information disclosure and external auditor requirements are positively associated with banks' operational efficiency.

Centralization and optimal allocation of financial resources reduce trade costs, improve transaction efficiency, and promote the operation of regional economies. Doh and Kim (2014) suggested that governments provide financial support for regional small and medium enterprise (SME) innovations, and state that there is a positive relationship between the technological development assistance of the government and new design registrations of regional SMEs. Guan and Yam (2015) maintained that the centrally-planned funding system was ineffective in enhancing technological advances for Chinese manufacturing firms in the 1990s. While direct earmarks did not have significant effect in improving economic performance; they had negative impact on business innovation. However, the incentive systems of tax credits and special loans contribute to promoting firms' innovation capacity in China.

1.2. Financial infrastructure and safety

The financial infrastructure is the cornerstone of financial market development, and convenient transportation and well-developed infrastructure provide the most basic external conditions for financial agglomeration; cross-country enterprises and financial institutions entry will depend on these factors. Under these terms, savings can be effectively mobilized within productive capital, and channelled to the most productive uses, in order to optimize the development of financial markets (Moskow 2002). Whittaker (2002) claimed that financial systems facilitate investment, and support banking and services to customers, with all of these contributing directly and indirectly to the national GDP, thus, they should be considered as a chief element of critical national infrastructure. Amable and Chatelain (2001) emphasized that strong financial infrastructure can enhance the efficiency of banks (Von Furstenberg, Fratianni 1996), such as decreasing the market power of financial intermediaries, lowering the cost of capital, and increasing the number of depositors; thereby promoting economic growth.

Financial ecological environments include the legal system, social honesty and credit, accounting and auditing standards, the intermediary service system, the relationship between

banks and firms, etc. Muniandy and Ali (2012) proposed that accounting practices are influenced by legal, political, and cultural aspects, as well as the capital market. If the accounting regulatory system of a country has been internationally accepted, it can assist the favourable process of international trade (Saudagaran, Diga 2000). Strict regulations on bank entry, limitations on bank activities, and repressing banks' conducting their business, all raise the cost of financial intermediation and have detrimental effect on financial development (Demirgüç-Kunt *et al.* 2003). Manson and Zaman (2001) stated that, while an audit report strengthens the believability of financial statements, the users of financial statements care more about the auditors' assessment of the going concern of the firm, and whether or not fraudulent or illegal acts emerge from the auditors' findings. Based on the above, this paper suggests that the financial ecological environment may be the prime criterion triggering regional financial center modernization.

Giannetti and Jentzsch (2013) illustrated that credit reporting systems are a critical part of financial markets, and that the borrowers' identification system has positive effective on financial intermediation and financial access. According to Treacy and Carey (2000), most large banks in the U.S. have internal rating systems, which are increasingly important in dealing with credit risks. With the changing financial environment, designing appropriate rating systems promotes their effectiveness. While credit cards have become the most popular means of payments around the world, they introduce credit risks for financial institutions, thus, building fraud detection systems has also been a development trend (Leonard 1995; Pavía *et al.* 2012). In addition, small enterprises are seriously affected by economic downturn, as they generate more credit risks due to changing business environments. Tsaih *et al.* (2004) commented that a credit scoring decision support system for small business loans can be easily modified to deal with the changing business environment. Tsai *et al.* (2011) noted that banks prefer to enter countries that have private credit bureaus or higher quality credit reporting systems, as they can reduce their information costs and obtain better quality information from the credit database (Brown, Zehnder 2010).

Since the development and application of the internet and computers, information systems play an increasingly vital role in business operations (Kankanhalli *et al.* 2003). Laws, regulations, new threats, and business objectives are all drivers, and information security risk management of business is paramount (Jirasek 2012), particularly in the finance industry. Luo (2011) cited many problems of information security in China, such as network security among enterprises, attacks on the fragile e-government system, a shortage of information security professionals, leaders lacking awareness of information security, and the imperfections of the relevant laws and regulations. The risk assessment of information security has started in China; thus, building and improving the foundation of risk assessment, enhancing information security risk assessment teams, and cultivating information security professionals are urgent and important (Fu, Xiao 2011; Zhiwei, Zhongyuan 2012).

1.3. Financial service

The loan market is a crucial part of financial center development, and international shocks are extensively disseminated through cross boarder credit markets (Giannetti, Laeven 2012).

Longstaff (2010) also considered that financial contagion is propagated in cross-markets with significant effect. In the early stages of economic development, a well-functioning credit market could assist the poor to accumulate wealth. Agostino *et al.* (2010) found that with energetic competition, local credit markets might stimulate banks to perform more accurate screening of borrowers/SMEs, in order that credit market competition raises the assigned efficiency of bank funds. With lower credit market friction in countries, financial reforms have reduced flaws, which lead to a decline in macroeconomic volatility (Cavalcanti 2010) and enhance stable economic development. In recent years, the barriers on foreign bank entry and activity have been largely cut in many countries, and the loan proportion from foreign banks has also gradually increased (Haselmann, Wachtel 2011), implying more extensive financial services.

Baum *et al.* (2011) stated that financial architecture plays a key role in SMEs by influencing the levels of financial development and economic growth. Ndikumana (2005) reported that when a country has a well-developed financial system, investing is easier with lower finance costs, which effectively elevates the level of domestic investment and long-term economic growth. Underdeveloped and imperfect financial markets might be globally excluded, and the information will not be smoothly propagated in cross-country communication (Yartey 2008). Bolbol *et al.* (2005) found that the development of financial structure consists of three issues: speeding the privatization of state business, widening foreign inflows, and stock market reforms, which contribute to domestic economic growth. Building a national financial market trading platform locally can optimize the allocation of financial resources, strengthen the radiation and influence of regional financial centers, and form the advantages and power of the finance industry. Building world-famous commercial city centers, such as the City of London, and Wall Street in New York City, enhance international visibility.

1.4. Financial institutions and human resources

Financial institutions are a cardinal brace in the construction of a regional financial center, and promote the comprehensive strength and competitiveness of the financial center, especially for large financial institutions and new entries. To avoid financial crises recurring, financial reform policies in Thailand particularly allowed greater foreign bank penetration; and an effective and stable financial system could be established (Thakor 2012). Okuda and Rungsomboon (2006) also presented that foreign and domestic banks have different functions; the former have advanced screening and monitoring techniques and experienced risk management skills to service multinational companies and large Thai companies, while the latter provides domestic service to SMEs and households. The introduction of large foreign financial institutions boosts the level of financial development. The higher the level of financial institutions, the more superior the economic growth (Bekaert *et al.* 2005). Luo (2012) was convinced that capital market development is regarded as the pivotal aspect of a city's financial center, including the number of firms listed, the number of securities listed, and the depth of market capitalization. A financial center in a central city involves the coexistence of financial institutions and large numbers of professional services, thus, it must be supported by talents. Balan and Knack (2012) indicated that professional's morality and ability are associated

with higher per-capital incomes, and influence aggregate economic performance; moreover, CEOs' ethical leadership is an important factor for top management team effectiveness (De Hoogh, Den Hartog 2008).

Based on literature review, as noted above, and according to interviews with five government officials in the Guangdong Office, China Banking Regulatory Commission, three scholars in finance-related departments, and four managers from banks; based on literature review and through a pre-test questionnaire for choosing important criteria, the results as the following four perspectives (dimensions) and 21 affiliated criteria of influence are as shown in Table 1. The 21 criteria form the basis of the pre-test questionnaire for Guangzhou regional financial center modernization development.

Table 1. The performance evaluation factors for the pre-test questionnaire

Perspectives (or called Dimensions)			
Government policy	Financial infrastructure and safety	Financial service	Financial institutions and human resources
Criteria			
Financial liberalization	Financial infrastructure	Credit market	Large financial institutions
Financial regulations modernization	Financial ecological environment	Financial structure	New financial institutions
Financial industry development policy	Financial street	National financial market trading platform	Listed financial enterprises
Financial supervision and regulation	Credit systems	Financial capital management	Cultivating financial professionals
Allocation of financial resources	Electronic financial and information safety	The diversification of the financial products	Financial employees' morality
		The quality of the financial products	

2. Building a new hybrid MADM model for improving regional financial center modernization development

The MADM model is developed based on the abovementioned studies, and is selected as a fitting method for the assessment of regional financial center modernization development; decision-makers can use the outcome for improving and reducing the performance gaps in each criterion. This section includes four sub-sections: first, the data collection process is as illustrated in Subsection 2.1; the DEMATEL technique is introduced; and information of how to build an influential network relation map (INRM) is proposed in subsection 2.2; the next chapter discusses how to find the influential weights of DANP, as based on the total influence relation matrix of the DEMATEL technique in Subsection 2.3; finally, application of the modified VIKOR method transforms the performance values into normalized performance gaps, as based on aspiration-worst level, is presented in Subsection 2.4. The research processes are illustrated in Figure 1.

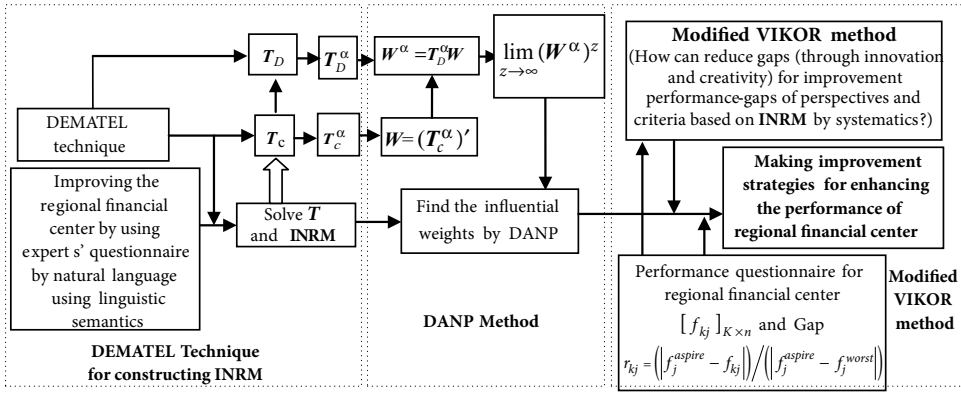

Fig. 1. Model procedure for new multiple attribute decision making for the regional financial center modernization

2.1. Data collection

The research sample was collected from professional personnel and scholars who have a deep knowledge of the regional financial center (i.e., refers to the experts in practical experience), through in-depth interviews and questionnaire surveys. The researchers collected the viewpoints of experts regarding the effects of the evaluation criteria of the four dimensions, as described above, on the modernization development of a regional financial center; 30 questionnaire experts were assigned in the second phase, including 12 government officials from the Guangdong office, China Banking Regulatory Commission, 10 presidents or managers from financial institutions, and 8 university scholars in finance-related departments. Each interview took 60–90 minutes. In the first phase (pre-test questionnaire), the potential factors affecting the modern development of the Guangzhou regional financial center are listed. These factors were compiled based on existing studies and expert opinions to select the most important factors (important scales based on triangular fuzzy numbers, with a mean scoring of 8 point and above in range-scales from 0 to 10 points). The important scales were preserved to facilitate the design of the second phase questionnaire, which was followed by further selection, with the results elaborated in Table 2. The results were subject to empirical analysis, as based on research methodology stated herein. In light of experts' opinions, the questionnaires assessed the relationship between mutually influential criteria, with a scale ranging from 0 to 4 points, where scores represented a range from "completely no influence (0)" to "very high influence (4)". Respondents proposed the degree of direct influence that each perspective (dimension) and criterion (factors) exerts on another perspective and criterion. The DEMATEL technique was used to analyze the data from the questionnaires to reveal the relationships among the perspectives and criteria (Appendix B3.1 and B3.2).

Table 2. Regional financial center modernization evaluation factors

Dimensions/Criteria	Descriptions	References
Government policy (*A*)		
Financial industry development policy (a_1)	Include the financial incentive system, tax abatements or tax credits for enterprises promoted by Guangzhou government;	Deng *et al.* (2012); Felix and Hines Jr. (2013); Gertler *et al.* (2012); Thakor (2012); Tung and Cho (2000)
Financial supervision and regulation (a_2)	Financial administrative authorities monitoring financial transactions and maintaining financial market stability;	Allen *et al.* (2012); Barth *et al.* (2013); Baum *et al.* (2011); Buck and Schliephake (2013); Klomp and Haan (2012); Lucey and Zhang (2011)
Allocation of financial resources (a_3)	The central and local governments inject funds into the financial sector.	Doh and Kim (2014); Guan and Yam (2015)
Financial infrastructure and safety (*B*)		
Financial infrastructure (b_1)	Include convenient transportation and communication, and good capital flow environment;	Moskow (2002); Whittaker (2002)
Financial ecological environment (b_2)	Refers to the legal system, the social honesty and credit, the accounting and auditing standards, the intermediary service system and the relationship between banks and firms;	Demirgüç-Kunt *et al.* (2003); Manson and Zaman (2001); Muniandy and Ali (2012); Saudagaran and Diga (2000)
Credit systems (b_3)	Build division and enterprise credit systems; establish financial credit infrastructure and systems; construct credit records, credit evaluation, credit monitoring, credit information disclosure and penalization systems, etc.;	Brown and Zehnder (2010); Giannetti and Jentzsch (2013); Leonard (1995); Pavía *et al.* (2012); Treacy and Carey (2000); Tsai *et al.* (2011); Tsaih *et al.* (2004)
Electronic financial and information safety (b_4)	Enhance electronic financial transaction information security.	Fu and Xiao (2011); Jirasek (2012); Kankanhalli *et al.* (2003); Luo (2011); Zhiwei and Zhongyuan (2012)
Financial service (*C*)		
Credit market (c_1)	Found a perfect credit market, such as loan institutions to SMEs;	Agostino *et al.* (2010); Cavalcanti (2010); De las Mercedes Adamuz and Cortés (2015); Giannetti and Laeven (2012); Haselmann and Wachtel (2011); Miller (2015)
Financial structure (c_2)	Whether or not Guangzhou financial industry (banking, insurance and security) development is unbalanced;	Baum *et al.* (2011); Yartey (2008)
National financial market trading platform (c_3)	Establish a national financial market trading platform, such as the Guangzhou trade center in financial assets and foreign exchange market.	An *et al.* (2015); Bolbol *et al.* (2005)

End of Table 1

Financial institutions and human resources (*D*)		
Large financial institutions (d_1)	Establish global and domestic influential financial institutions or introduce foreign financial institutions;	Okuda and Rungsomboon (2006); Thakor (2012)
New financial institutions (d_2)	Set up a variety of new financial institutions;	Luo (2012)
Listed financial enterprises (d_3)	Increase the number of finance-related companies listed in Guangzhou;	Luo (2012)
Financial employees' morality (d_4)	The quality and morality of financial professionals include CEO, managers and the staff.	De Hoogh and Den Hartog (2008); Balan and Knack (2012)

2.2. DEMATEL technique

The DEMATEL technique was first developed by the Geneva Research Centre (Fontela, Gabus 1976) for the purpose of showing a network relation diagram, and a structural model for understanding specific societal problems. These basic concepts were used to create a series of new hybrid MADM models for solving complex and dynamic real world problems (Peng, Tzeng 2013; Tzeng, Huang 2012; Lu *et al.* 2013, 2015; Hu *et al.* 2015; Chen, Chi 2015; Liou *et al.* 2014, 2016). The DEMATEL technique involves three steps, detailed as follows.

Step 1: *Calculate the direct influence relation average matrix* ***B***. Assume the number of experts H and the number of criteria n are asked to propose that the pairwise comparisons between any two criteria are denoted by, and are given, an integer score of 0, 1, 2, 3, or 4, expressing the range from "absolutely no influence (0)" to "very high influence (4)" by natural language in linguistics (e.g., semantics), and showing the degree that each criterion i affects each criterion j. The answers by each expert form a $n \times n$ non-negative matrix $\boldsymbol{X}^h = [x_{ij}^h]_{n\times n}$, $h = 1,2,...,H$, where $\boldsymbol{X}^1,...,\boldsymbol{X}^h,...,\boldsymbol{X}^H$ are the answer matrices by the H experts in practical experience, and the elements of $\boldsymbol{X}^h$ are denoted by x_{ij}^h from expert h. Thus, an $n \times n$ average matrix $\boldsymbol{B}$ of all experts given can be built by Eq. (1):

$$\boldsymbol{B} = \begin{bmatrix} b_{11} & \cdots & b_{1j} & \cdots & b_{1j} \\ \vdots & & \vdots & & \vdots \\ b_{i1} & \cdots & b_{ij} & \cdots & b_{in} \\ \vdots & & \vdots & & \vdots \\ b_{n1} & \cdots & b_{nj} & \cdots & b_{nn} \end{bmatrix}. \quad (1)$$

The average scores of the H experts are $b_{ij} = \frac{1}{H}\sum_{h=1}^{H} x_{ij}^h$. The average matrix is called the initial direct relation matrix $\boldsymbol{B}$, and represents the degree of influence one criterion exerts on another, as well as the degree of influence it receives from other criteria.

Step 2: *Normalize the initial direct influence relation matrix.* The normalized initial direct influence relation matrix $\boldsymbol{D}$ is acquired by normalizing the average matrix $\boldsymbol{B}$. The matrix $\boldsymbol{D}$ is easily derived from Eqs. (2) and (3), whereby all principal diagonal criteria are equal to zero:

$$\boldsymbol{D} = s \cdot \boldsymbol{B}; \tag{2}$$

$$s = \min\left\{\frac{1}{\max_{1\le i\le n}\sum_{j=1}^{n} b_{ij}}, \frac{1}{\max_{1\le j\le n}\sum_{i=1}^{n} b_{ij}}\right\}. \tag{3}$$

Step 3: *Derive the total influence-relation matrix* $\boldsymbol{T}$. A continuous decrease of the indirect effects of problems moves with the powers of the matrix $\boldsymbol{D}$, e.g. $\boldsymbol{D}^2, \boldsymbol{D}^3, \ldots, \boldsymbol{D}^{\infty}$, and $\lim_{q\to\infty} \boldsymbol{D}^q = [0]_{n\times n}$, for $\lim_{q\to\infty}(\boldsymbol{I} + \boldsymbol{D} + \boldsymbol{D}^2 + \ldots + \boldsymbol{D}^q) = (\boldsymbol{I} - \boldsymbol{D})^{-1}$, where $\boldsymbol{I}$ is a $n \times n$ unit matrix. The total influence relation matrix $\boldsymbol{T}$ is a $n \times n$ matrix, and is defined by $\boldsymbol{T} = \left[t_{ij}\right]_{n\times n}, i, j = 1,2,\ldots,n$ as shown in Eq. (4):

$$\begin{aligned}\boldsymbol{T} &= \boldsymbol{D} + \boldsymbol{D}^2 + \ldots + \boldsymbol{D}^q \\ &= \boldsymbol{D}(\boldsymbol{I} + \boldsymbol{D} + \boldsymbol{D}^2 + \ldots + \boldsymbol{D}^{q-1}) \\ &= \boldsymbol{D}(\boldsymbol{I} + \boldsymbol{D} + \boldsymbol{D}^2 + \ldots + \boldsymbol{D}^{q-1})(\boldsymbol{I} - \boldsymbol{D})(\boldsymbol{I} - \boldsymbol{D})^{-1} \\ &= \boldsymbol{D}(\boldsymbol{I} - \boldsymbol{D})^{-1}, \text{ when } \lim_{q\to\infty} \boldsymbol{D}^q = [0]_{n\times n}.\end{aligned} \tag{4}$$

The total influence relation matrix $\boldsymbol{T}$ of INRM can be acquired by Eq. (4). Eqs. (5) and (6) are used to generate each row sum and column sum in the matrix $\boldsymbol{T}$, respectively:

$$\boldsymbol{d} = (d_i)_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = (d_1,\ldots,d_i,\ldots,d_n)'; \tag{5}$$

$$\boldsymbol{r} = (r_j)_{n\times 1} = (r_j)'_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]'_{1\times n} = (r_1,\ldots,r_j,\ldots,r_n)', \tag{6}$$

where d_i is the sum of a row in the total influence relation matrix $\boldsymbol{T}$, which represents the total effects (both direct and indirect) of criterion/perspective *i* on the all other criteria/perspectives $\left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1}$. Similarly, r_j is the column sum in the total influence relation matrix $\boldsymbol{T}$, which represents the total effects (both direct and indirect) of criterion/perspective *j* received from the all other criteria/perspectives $\left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n}$. Thus, when $i = j$, $(d_i + r_i)$ offers an index of the strength of the total influences given and received, that is $(d_i + r_i)$ indicates the degree of importance that criterion/perspective *i* plays in the system. In addition, $(d_i - r_i)$ provides an index of the degree of the cause of total influence. If $(d_i - r_i)$ is positive, then criterion/perspective *i* is a net causer, and if $(d_i - r_i)$ is negative, then criterion/perspective *i* is a net receiver.

2.3. Based on the DEMATEL technique to find the influential weights of DANP

Besides using DEMATEL to identify the inter-relationships between the fourteen factors, this study also attempted to obtain more precise "influential weights" in line the real world problem. "Influential weights of DANP (DEMATEL-based ANP)" is in line with the needs for solving practical issues to relax or relieve some unreasonable assumptions in AHP and ANP. Saaty (1996) proposed an ANP to solve the dependence and feedback problems only between dimensions (or called clusters), criteria (inner dimension/cluster) in diagonal matrix until assumed to be independent (zero matrix, $\boldsymbol{W}^{ii} = \left[0\right]$) or assumed self-relation (Iden-

tity matrix, ***I***), and the weighted super-matrix obtained by using equal weights. This ANP overcomes the limitations of the Analytic Hierarchy Process (AHP) that assuming criteria (inner and outer dimension/cluster) to be all independent. The difference of the two methods is that ANP can be applied to the decision-making problems of the interrelationship in outer dimensions (or called clusters), while AHP assumes the independent relationship between outer and inner dimensions (i.e., all dimension and criteria). If there exists an influential interrelationship between dimensions/criteria that is not taken into account, it could affect the outcome of the decision. Therefore, this study used a new hybrid MADM model for improving the modernization development of China's regional financial center, and adopted DEMATEL technique via knowledge domain of experts in practical experience, in order to build influence relation matrix for constructing influential network relation (INRM) and determining the influential weights of DANP (DEMATEL-based ANP) based on the basic concept of ANP (Saaty 1996). The aim is to solve those problems (Chen, Tzeng 2015) that resemble real world problems, in instead of traditional applications. Thus, the influential weights of DANP (DEMATEL–based ANP) contain the following steps.

Step 4: *Total influence relation matrix* $\boldsymbol{T}_C$. DEMATEL is used to build total influence relation matrix $\boldsymbol{T}_C$ from each perspective (dimension or cluster), with different degrees of influence relation for the criteria, as shown in Eq. (7), where $\sum_{j=1}^{m} m_j = n$, $m < n$, and $\boldsymbol{T}_c^{ij}$ as a $m_i \times m_j$ matrix:

$$\boldsymbol{T}_C = \begin{array}{c} \\ D_1 \\ \vdots \\ D_i \\ \vdots \\ D_m \end{array} \begin{array}{c} \begin{array}{cccccc} D_1 & & D_j & & D_m \\ c_{11}\ldots c_{1m_1} & \cdots & c_{j1}\ldots c_{jm_j} & \cdots & c_{m1}\ldots c_{mm_m} \end{array} \\ \begin{bmatrix} \boldsymbol{T}_c^{11} & \cdots & \boldsymbol{T}_c^{1j} & \cdots & \boldsymbol{T}_c^{1m} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{i1} & \cdots & \boldsymbol{T}_c^{ij} & \cdots & \boldsymbol{T}_c^{im} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{m1} & \cdots & \boldsymbol{T}_c^{mj} & \cdots & \boldsymbol{T}_c^{mm} \end{bmatrix}_{n\times n | m<n,\ \sum_{j=1}^{m} m_j = n} \end{array} \begin{array}{l} \\ c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \\ c_{i1} \\ c_{i2} \\ \vdots \\ c_{im_i} \\ c_{m1} \\ c_{m2} \\ \vdots \\ c_{mm_m} \end{array}, \tag{7}$$

where D_m is the mth cluster; c_{mm} is the mth criterion in the mth dimension; and $\boldsymbol{T}_C^{ij}$ is a submatrix of the influence relation by the criteria from a comparison of the ith dimension and the jth dimension. In addition, if the ith dimension has no influence on the jth dimension, then submatrix $\boldsymbol{T}_C^{ij} = [0]$, shows independence (no influence relation) in each other criterion.

Step 5: *Form an un-weighted super-matrix* ***Y***. Normalize the total influence relation matrix $\boldsymbol{T}_C$ as shown in Eq. (8):

$$\boldsymbol{T}_C^{\alpha} = \begin{array}{c} \\ D_1 \\ \vdots \\ D_i \\ \vdots \\ D_m \end{array} \begin{array}{c} \begin{array}{cccccc} D_1 & & D_j & & D_m \\ c_{11}\ldots c_{1m_1} & \cdots & c_{j1}\ldots c_{jm_j} & \cdots & c_{n1}\ldots c_{mm_m} \end{array} \\ \begin{bmatrix} \boldsymbol{T}_c^{\alpha 11} & \cdots & \boldsymbol{T}_c^{\alpha 1j} & \cdots & \boldsymbol{T}_c^{\alpha 1m} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{\alpha i1} & \cdots & \boldsymbol{T}_c^{\alpha ij} & \cdots & \boldsymbol{T}_c^{\alpha im} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{T}_c^{\alpha m1} & \cdots & \boldsymbol{T}_c^{\alpha mj} & \cdots & \boldsymbol{T}_c^{\alpha mm} \end{bmatrix}_{n\times n | m<n,\ \sum_{j=1}^{m} m_j = n} \end{array} \begin{array}{l} \\ c_{11} \\ c_{12} \\ \vdots \\ c_{1m_1} \\ c_{i1} \\ c_{i2} \\ \vdots \\ c_{im_i} \\ c_{m1} \\ c_{m2} \\ \vdots \\ c_{mm_m} \end{array}, \tag{8}$$

where $\boldsymbol{T}_C^{\alpha}$ denotes the normalizing total influence relation matrix, and $\boldsymbol{T}_c^{\alpha 14}$ is derived from Eqs. (9) and (10). Similarly, $\boldsymbol{T}_c^{\alpha mm}$ can be obtained:

$$t_i^{14} = \sum_{j=1}^{m_4} t_{ij}^{14}, i = 1, 2, \cdots, m_1; \tag{9}$$

$$\boldsymbol{T}_c^{\alpha 14} = \begin{array}{c} \\ c_{11} \\ \vdots \\ c_{1i} \\ \vdots \\ c_{1m_1} \end{array} \begin{array}{c} \begin{array}{cccccc} c_{41} & \cdots & c_{4j} & \cdots & c_{4m_4} \end{array} \\ \begin{bmatrix} t_{11}^{14}/t_1^{14} & \cdots & t_{1j}^{14}/t_1^{14} & \cdots & t_{1m_4}^{14}/t_1^{14} \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{14}/t_i^{14} & \cdots & t_{ij}^{14}/t_i^{14} & \cdots & t_{im_4}^{14}/t_i^{14} \\ \vdots & & \vdots & & \vdots \\ t_{m_1 1}^{14}/t_{m_1}^{14} & \cdots & t_{m_1 j}^{14}/t_{m_1}^{14} & \cdots & t_{m_1 m_4}^{14}/t_{m_1}^{14} \end{bmatrix} \end{array} = \begin{bmatrix} t_{11}^{\alpha 14} & \cdots & t_{1j}^{\alpha 14} & \cdots & t_{1m_4}^{\alpha 14} \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{\alpha 14} & \cdots & t_{ij}^{\alpha 14} & \cdots & t_{im_4}^{\alpha 14} \\ \vdots & & \vdots & & \vdots \\ t_{m_1 1}^{\alpha 14} & \cdots & t_{m_1 j}^{\alpha 14} & \cdots & t_{m_1 m_4}^{\alpha 14} \end{bmatrix}. \tag{10}$$

According to the pair-wise comparisons with the criteria, and based on the basic concept of ANP, the un-weighted super-matrix $\boldsymbol{W}$ can be obtained by transposing the normalized influence-relation matrix $\boldsymbol{T}_C^{\alpha}$ by dimensions (clusters), i.e. $\boldsymbol{W} = (\boldsymbol{T}_C^{\alpha})'$, as shown in Eq. (11):

$$\boldsymbol{W} = (\boldsymbol{T}_C^{\alpha})' = \begin{array}{c} \\ D_1 \\ \\ \vdots \\ \\ D_j \\ \vdots \\ \\ \\ D_m \end{array} \begin{array}{c} \begin{array}{cccc} c_{11} & & & \\ c_{12} & & & \\ \vdots & & & \\ c_{1m_1} & & & \\ \vdots & & & \\ c_{j1} & & & \\ c_{j2} & & & \\ \vdots & & & \\ c_{jm_j} & & & \\ \vdots & & & \\ c_{m1} & & & \\ c_{m2} & & & \\ \vdots & & & \\ c_{mm_m} & & & \end{array} \\ \begin{array}{cccccc} D_1 & & D_i & & D_m \\ c_{11} \ldots c_{1m_1} & \ldots & c_{i1} \ldots c_{im_i} & \cdots & c_{m1} \ldots c_{mm_m} \end{array} \\ \begin{bmatrix} \boldsymbol{W}^{11} & \cdots & \boldsymbol{W}^{i1} & \cdots & \boldsymbol{W}^{m1} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{W}^{1j} & \cdots & \boldsymbol{W}^{ij} & \cdots & \boldsymbol{W}^{mj} \\ \vdots & & \vdots & & \vdots \\ \boldsymbol{W}^{1m,} & \cdots & \boldsymbol{W}^{im} & \cdots & \boldsymbol{W}^{mm} \end{bmatrix} \end{array} \quad n \times n | m < n, \sum_{j=1}^{m} m_j = n \tag{11}$$

Step 6*: Obtain the weighted super-matrix* $\boldsymbol{W}^{\alpha}$. The total influence-relation matrix $\boldsymbol{T}_D$ of dimensions is derived according to the DEMATEL technique, as given by Eq. (12):

$$\boldsymbol{T}_D = \begin{bmatrix} t_{11} & \cdots & t_{1j} & \cdots & t_{1m} \\ \vdots & & \vdots & & \vdots \\ t_{i1} & \cdots & t_{ij} & \cdots & t_{im} \\ \vdots & & \vdots & & \vdots \\ t_{m1} & \cdots & t_{mj} & \cdots & t_{mm} \end{bmatrix}_{m \times m}. \tag{12}$$

The normalized total influence-relation matrix $\boldsymbol{T}_D^{\alpha}$ of dimensions can be obtained through the total influence-relation matrix $\boldsymbol{T}_D$ divided by $d_i = \sum_{j=1}^{m} t_{ij}$, $i = 1, 2, ..., m$, as shown in Eq. (13):

$$\boldsymbol{T}_{\mathrm{D}}^{\alpha} = \begin{bmatrix} t_{11}/\mathrm{d}_1 & \cdots & t_{1j}/d_1 & \cdots & t_{1m}/d_1 \\ \vdots & & \vdots & & \vdots \\ t_{i1}/d_i & \cdots & t_{ij}/d_i & \cdots & t_{im}/d_i \\ \vdots & & \vdots & & \vdots \\ t_{m1}/d_m & \cdots & t_{mj}/d_m & \cdots & t_{mm}/d_m \end{bmatrix}_{m \times m} = \begin{bmatrix} t_{11}^{\alpha D} & \cdots & t_{1j}^{\alpha D} & \cdots & t_{1m}^{\alpha D} \\ \vdots & & \vdots & & \vdots \\ t_{i1}^{\alpha D} & \cdots & t_{ij}^{\alpha D} & \cdots & t_{im}^{\alpha D} \\ \vdots & & \vdots & & \vdots \\ t_{m1}^{\alpha D} & \cdots & t_{mj}^{\alpha D} & \cdots & t_{mm}^{\alpha D} \end{bmatrix}_{m \times m}. \tag{13}$$

The normalized $\boldsymbol{T}_D^{\alpha}$ and the un-weighted super-matrix $\boldsymbol{W}$ (shown as Eq. (11)), and the weighted super-matrix $\boldsymbol{W}^{\alpha}$ (normalized super-matrix) can be easily obtained by Eq. (14), where $t_{ij}^{\alpha D}$ is a scalar and $\sum_{j=1}^{m} m_j = n$:

$$\boldsymbol{W}^{\alpha} = \boldsymbol{T}_D^{\alpha}\boldsymbol{W} = \begin{array}{c} \\ D_1 \\ \\ \\ \\ \vdots \\ \\ D_j \\ \\ \vdots \\ \\ \\ D_m \end{array} \begin{array}{c} \begin{array}{cccccc} D_1 & & D_i & & D_m \\ c_{11} & \cdots & c_{i1} \cdots c_{im_i} & \cdots & c_{m1} \cdots c_{mm_m} \end{array} \\ \begin{bmatrix} t_{11}^{\alpha D} \times \boldsymbol{W}^{11} & \cdots & t_{i1}^{\alpha D} \times \boldsymbol{W}^{i1} & \cdots & t_{m1}^{\alpha D} \times \boldsymbol{W}^{m1} \\ \vdots & & \vdots & & \vdots \\ t_{1j}^{\alpha D} \times \boldsymbol{W}^{1j} & \cdots & t_{ij}^{\alpha D} \times \boldsymbol{W}^{ij} & \cdots & t_{mj}^{\alpha D} \times \boldsymbol{W}^{mj} \\ \vdots & & \vdots & & \vdots \\ t_{1m}^{\alpha D} \times \boldsymbol{W}^{1m} & \cdots & t_{im}^{\alpha D} \times \boldsymbol{W}^{im} & \cdots & t_{mm}^{\alpha D} \times \boldsymbol{W}^{mm} \end{bmatrix} \end{array} . \quad (14)$$

Step 7: *Calculate the limit super-matrix* $\boldsymbol{W}^{\alpha}$. Limit the weighted super-matrix by raising it to the *z*th power, until the super-matrix has converged and become a stable super-matrix. The global priority vectors are obtained, which are called the influential weights of DANP (DEMATEL-based ANP), such as $\lim_{z\to\infty}(\boldsymbol{W}^{\alpha})^z$, where z represents any number of power.

In brief, according to the above process, the INRM and the influence weights of DANP can be obtained. Both the above (INRM and DANP) can be used to cope with the problem of interdependence and feedback in order to innovate/create the best systematic improvement strategies to reduce the gaps of criteria performance, in order that all criteria can achieve the aspiration level.

2.4. Modified VIKOR method

The VIKOR method, as developed by Opricovic and Tzeng (2004, 2007), solves MADM problems with conflicting criteria. This method is used as the basic concept of the TOPSIS method (Hwang, Yoon 1981) on Euclidean distances to the positive ideal (this research adopts the aspiration level) and the negative ideal (this research adopts the worst level) solutions, and TOPSIS used the class Euclidean distance function (Yu 1973), as based the concept of the positive ideal and negative ideal solutions; then Opricovic and Tzeng (2004) found that the TOPSIS method cannot be used in ranking or selection, and proposed the VIKOR method to replace the TOPSIS method, by comparing the preference distance of all real alternatives in order to stay close to the positive-ideal point; however, this research adopted the basic idea of the traditional thinking of the VIKOR method to replace staying close to the aspiration level (Liu *et al.* 2012; Chen 2015; Hu *et al.* 2015). The gap concept measures the proximity to the positive ideal point in order to modify the aspiration level point. In a different view-point, the relative good solution (ideal solution) from the existing alternatives (traditional VIKOR method) is replaced by the aspiration levels (modified VIKOR method), in order to support DM(s) to pursue excellence. The idea of aspiration levels was proposed by the Nobel Prize Laureate H. A. Simon (1955, 1956, and 1959), and replaced the classic selection or optimization decision based on Min-Max values by searching for the aspiration levels at each stage,

and the decision process would be regarded as the pursuit of continuous improvements or enhancements. The modified VIKOR method is, as follows:

Step 1: *Derive the positive-ideal solution and negative-ideal solution replaced by the aspiration levels and the worst value to fit today's real world situation*. Define the best value (aspiration level) shown as f_j^{aspire} in *j* criterion and the worst value f_j^{worst} for all criteria, which can be acquired from the traditional form to the modified form:

1) Traditional approach for deriving the positive-ideal solution and negative-ideal solution as follows:

The positive-ideal solution: $\boldsymbol{f}^* = (f_1^*,...,f_j^*,...,f_n^*)$, where $f_j^* = \max_k \{f_{kj} \mid k = 1,2,...,K\}$;

The negative-ideal solution: $\boldsymbol{f}^- = (f_1^-,...,f_j^-,...,f_n^-)$, where $f_j^- = \min_k \{f_{kj} \mid k = 1,2,...,K\}$.

2) The modified approach for replacement by the aspiration level and the worst value, as follows:

The aspiration level: $\boldsymbol{f}^{aspire} = (f_1^{aspire},...,f_j^{aspire},...,f_n^{aspire})$, where f_j^{aspire} is an aspiration level, or called the best value;

The worst values: $\boldsymbol{f}^{worst} = (f_1^{worst},...,f_j^{worst},...,f_n^{worst})$, where f_j^{worst} is a worst value.

In this study, the performance range-scores from 0 to 10 (very bad ←0,1,2,...,9,10→ very good) are used with natural language in the linguistic/semantic questionnaire, thus, the aspiration level takes the highest score of 10 and the worst value takes the value of 0. Hence, $f_j^{aspire} = 10$ is defined as the aspiration level and $f_j^{worst} = 0$ as the worst value, it can avoid choosing the best among inferior choices/options/alternatives. In other words, it avoids "picking the best apple from a barrel of rotten apples".

Step 2: *Determine the mean group utility S_k for the gap and maximal gap Q_k for prioritizing improvement*. These values can be calculated using Eqs. (15) and (16), respectively:

$$S_k = \sum_{j=1}^{n} w_j r_{kj} = \sum_{j=1}^{n} w_j (|f_j^{aspire} - f_{kj}|) / (|f_j^{aspire} - f_j^{worst}|); \tag{15}$$

$$Q_k = \max_j \{(|f_j^{aspire} - f_{kj}|) / (|f_j^{aspire} - f_j^{worst}|) \mid j = 1,2,...,n\}, \tag{16}$$

where S_k is defined as the normalized ratio of distance to the aspiration level, which implies the synthesized gap for the criteria. On the other hand, Q_k is defined as the normalized ratio of distance to the worst value, which implies the maximal gap in *j* criteria for priority improvement. Here, w_j indicates the influential weights for the criteria obtained from DANP, and r_{kj} indicates the normalized gap of the distance to the aspiration level.

Step 3: *Obtain the comprehensive indicator R_k for ranking and selection in the traditional VIKOR approach*. The values are given by:

$$R_k = v(S_k - S^*) / (S^- - S^*) + (1-v)(Q_k - Q^*) / (Q^- - Q^*), \tag{17}$$

where $S^* = \min_k S_k$, $S^- = \max_k S_k$, $Q^* = \min_k Q_k$, $Q^- = \max_k Q_k$ and $0 \le v \le 1$, where v denotes the weight on the strategy of the maximum group utility, and 1-v is the weight on the individual regret (maximal gap for priority improvement). Therefore, Eq. (17) can be rewritten as $R_k = vS_k + (1-v)Q_k$ in the modified VIKOR to replace the traditional VIKOR approach, when $S^* = S^{aspire} = 0$ and $Q^* = Q^{aspire} = 0$ as well as $S^- = S^{worst} = 1$ and $Q^- = Q^{worst} = 1$ are set. If $v = 1$ represents only the consideration of the average gap weighting integration, then

$v = 0$ can be regarded as the maximum gap regarding the improvement priority. Generally speaking, $v = 0.5$ can be set, but can be adjusted depending on expert opinion in the value integration (because value measure is a non-additive situation in the real world).

All in all, the modified VIKOR can be used in the ranking and selection of alternatives, and for the improvement performance-gaps of criteria, as based on INRM by systematics, to avoid "stop-gap piecemeal" and avoids "picking the best apple from a barrel of rotten apples", and can even be used to solve any daily or single issue (i.e., only one issue, no other alternatives) for improvement performance-gap in considering all perspectives (dimensions), criteria, etc.

3. An empirical case: an improvement plan for Guangzhou regional financial center modernization

This Section mainly discusses the current status and issues facing Guangzhou regional financial center modernization development as an example to demonstrate the suitability of the proposed new hybrid MADM model for solving real world problems. The priorities for performance improvement are based on the results of the questionnaire survey and evaluation process. A diagram of the empirical case study is illustrated in Figure 2.

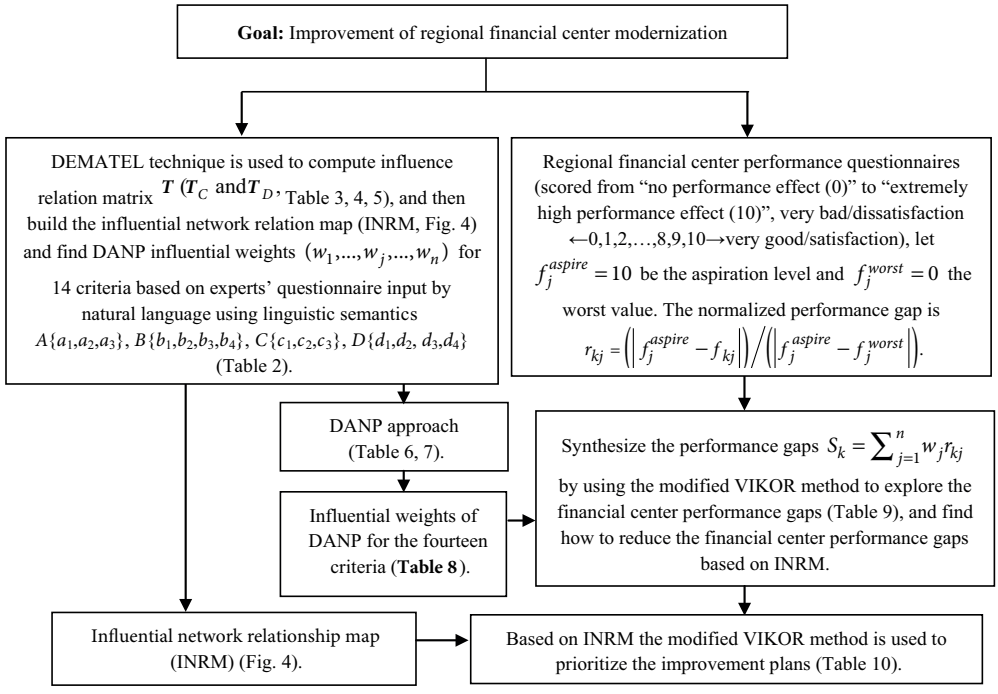

Fig. 2. Diagram of the process for the empirical case.

3.1. Background and problem statements

In order to promote Guangdong economic development and enhance financial industry modernization, the Guangzhou government established and promoted the "Guangzhou Regional Financial Center Construction Plan (2011–2020)" in May 2011, in an attempt to build a financial hub with a wide range of radiation, financial industry cohesion, and highly efficient financial services, in order to achieve the target of regional economic leveraged growth. While Guangzhou has a robust financial infrastructure, its development is unbalanced, meaning that banking and insurance industries are in progress, stock market development is slow, the proportion of direct finance is low, financial innovation is insufficient, and high-level talents are lacking. Building a financial center in Guangzhou is required to further deepen China's financial system, particularly financial management, financial administrative reform and adjustment, and more openness in financial institutions and financial markets. Guangzhou is a national central city and a comprehensive gateway, which intensifies the need for regional financial center modernization to improve local and national economic development. A map of China's regional financial center is as shown in Figure 3.

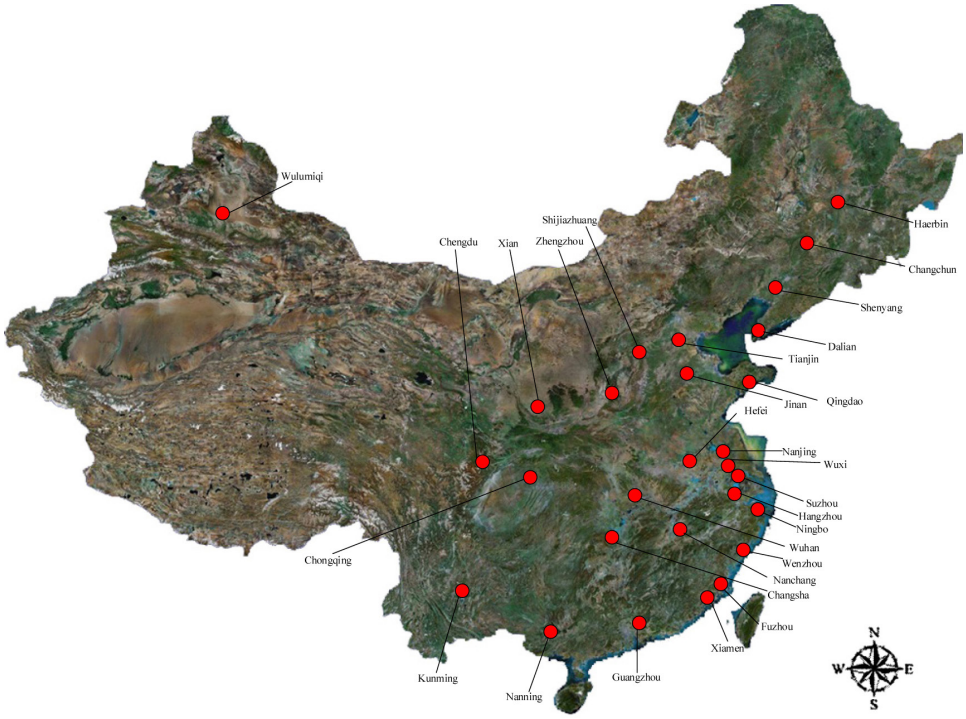

Fig. 3. China's regional financial center map

3.2. Operations and results

This paper proposes a model for the improvement of regional financial center modernization in China, which can be expected to improve its service quality and efficiency. The network structure is constructed based on the DEMATEL technique, which demonstrates the networks

of perspectives (dimensions) of regional financial center modernization. The average initial direct influence relation 4×4 matrix $\boldsymbol{B}$ is obtained through pair-wise comparisons to indicate the direction of the influences of dimensions on each other, and the normalized direct influence relation matrix $\boldsymbol{D}$ is measured using Eqs. (1) and (2). Then, the total influence matrix relation T_D of the dimensions, the total influence relation of matrix T_C of the criteria using Eqs. (3), (5), and (6), and the sum of the total influence given and received by each dimension and criterion can be shown, as in Tables 3 and 5. Significant confidence reached 98.8% in the results of the questionnaire survey by experts in practical experience (see "Note" of Table 4). These two total influence relation matrix $\boldsymbol{T}_D$ and $\boldsymbol{T}_C$ can measure the influences, given d_i and received r_i, $d_i + r_i$ and $d_i - r_i$ for building the INRM to conduct the degree of relationship between the dimensions and the effect of one dimension on others, respectively; the total influence relation matrix of the criteria as shown in Table 4; a diagram of the INRM was constructed, as shown in Figure 4, which indicate that all perspectives are interdependent.

Table 3. Total influence relation matrix $\boldsymbol{T}_D$: four perspectives (or called Dimensions)

Perspectives	*A*	*B*	*C*	*D*	Row sum (d_i)	Column sum (r_i)	$d_i + r_i$	$d_i - r_i$
A	0.418	0.463	0.479	0.427	1.787	1.543	3.329	0.244(1)
B	0.391	0.400	0.428	0.382	1.602	1.637	3.239	–0.035(2)
C	0.378	0.397	0.388	0.365	1.528	1.682	3.210	–0.154(4)
D	0.356	0.377	0.386	0.331	1.450	1.505	2.955	–0.055(3)

Table 4. Total influence relation matrix $\boldsymbol{T}_C$: fourteen criteria

Criteria	a_1	a_2	a_3	b_1	b_2	b_3	b_4	c_1	c_2	c_3	d_1	d_2	d_3	d_4
a_1	0.375	0.451	0.474	0.458	0.495	0.490	0.465	0.500	0.506	0.489	0.467	0.471	0.428	0.404
a_2	0.432	0.376	0.457	0.439	0.488	0.491	0.458	0.494	0.492	0.459	0.445	0.456	0.414	0.408
a_3	0.409	0.420	0.364	0.427	0.457	0.454	0.435	0.460	0.465	0.446	0.425	0.426	0.390	0.386
b_1	0.364	0.375	0.387	0.318	0.411	0.415	0.399	0.407	0.415	0.401	0.384	0.387	0.350	0.352
b_2	0.399	0.413	0.412	0.399	0.378	0.450	0.426	0.452	0.451	0.425	0.418	0.419	0.379	0.389
b_3	0.377	0.383	0.391	0.380	0.424	0.358	0.407	0.428	0.430	0.415	0.394	0.387	0.357	0.361
b_4	0.384	0.401	0.402	0.400	0.441	0.444	0.353	0.445	0.444	0.430	0.406	0.403	0.362	0.371
c_1	0.345	0.355	0.363	0.350	0.387	0.387	0.366	0.329	0.392	0.378	0.364	0.360	0.326	0.324
c_2	0.391	0.394	0.409	0.390	0.430	0.428	0.409	0.431	0.370	0.415	0.393	0.398	0.366	0.364
c_3	0.369	0.380	0.397	0.381	0.412	0.412	0.408	0.409	0.428	0.341	0.391	0.398	0.348	0.346
d_1	0.371	0.372	0.384	0.374	0.413	0.415	0.392	0.415	0.422	0.394	0.323	0.374	0.347	0.349
d_2	0.377	0.386	0.401	0.384	0.420	0.420	0.398	0.417	0.431	0.391	0.377	0.330	0.346	0.356
d_3	0.334	0.346	0.350	0.342	0.373	0.376	0.364	0.379	0.378	0.356	0.341	0.340	0.266	0.317
d_4	0.305	0.326	0.325	0.314	0.356	0.355	0.328	0.351	0.360	0.340	0.330	0.337	0.307	0.253

Note: *Average difference in consensus gap-ratio* $(\%) = \frac{1}{n^2}\sum_i \sum_j \left(\frac{|t_{ij}^H - t_{ij}^{H-1}|}{t_{ij}^H} \right) \times 100\% = 1.2\% < 5\%$, i.e., significant confidence is 98.8%, where t_{ij}^{H-1} and t_{ij}^H denote the average scores of the experts for number of $H-1=29$ and $H=30$ respectively; and n denotes number of criteria, here n = 14 and 14 ×14 matrix.

An examination of Table 3 shows that the perspective of government policy (*A*) is the factor that has the most influential strength given and received (3.329 of the total sum $d_i + r_i$), followed by financial infrastructure and safety (*B*), financial service (*C*), and financial institutions and human resources (*D*), respectively. In other words, government policy (*A*) is the most important influential perspective. Moreover, since the value of $d_i - r_i$ for (*A*) dimension is positive, it means that this perspective affects the other perspectives, implying it should be

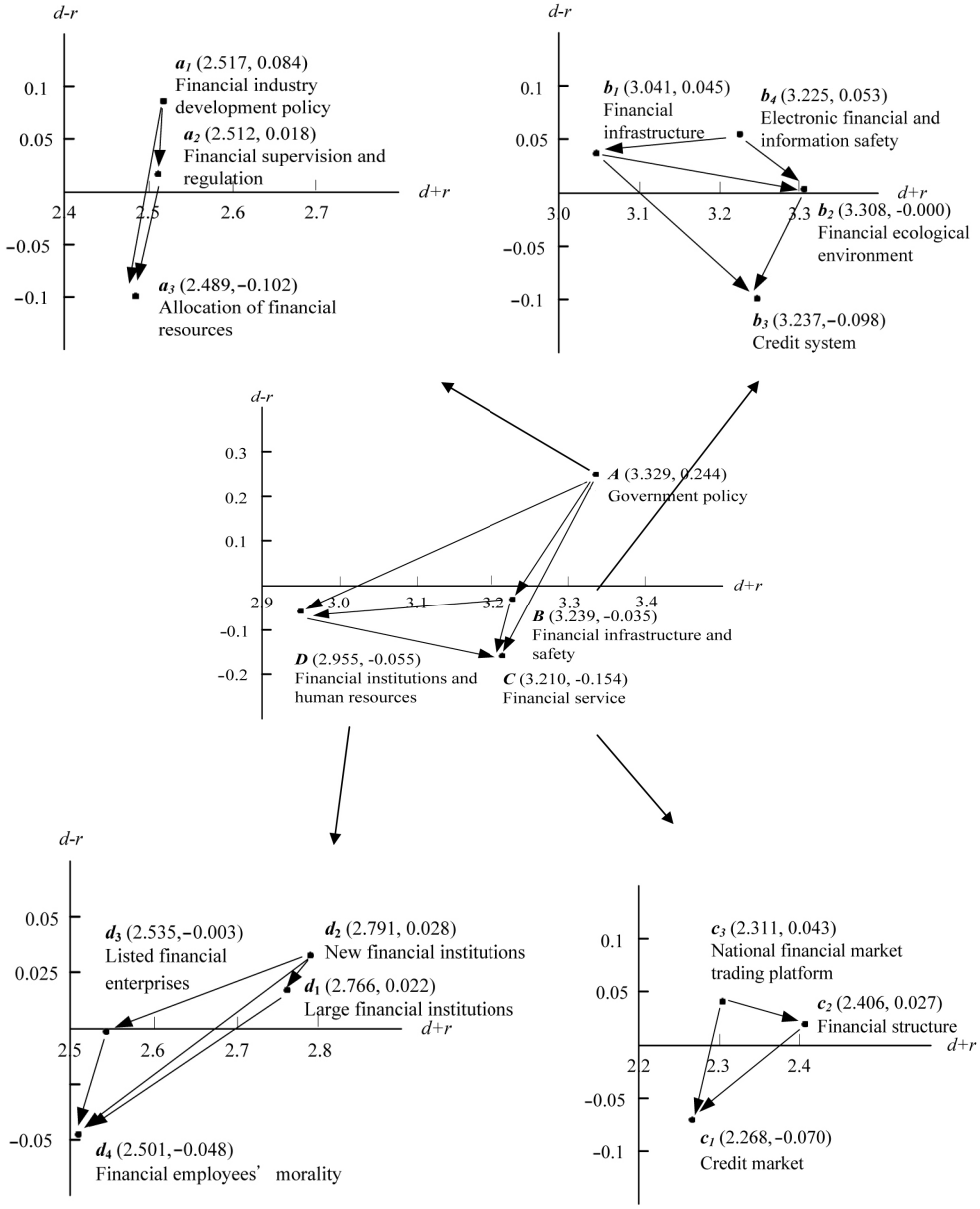

Fig. 4. The INRM of total influence relationships for the regional financial center modernization

a top priority for improvement. It can be seen that government policy (*A*) has the strongest degree of impact in a relationship that directly affects other dimensions, while financial service (*C*) is the most sensitive to impact. In order to achieve greater quality regional financial center modernization in the light of Table 3, government policy (*A*) is the first priority for improvement, as it can have an influential effect on the remaining dimensions. Therefore, the best strategy for improving regional financial center modernization is to improve government policy. The elements of the total influence matrix ***T*** are as listed in Table 4; which indicate that all criteria are interdependent (Group consensuses of 30 experts with the consensus value in average difference/gap only are 1.2% (less than 5%), and the significance of the confidence level reaches 98.8% (more than 95%, in "Note" of Table 4).

Table 5 shows the network of relationships influencing each criterion. The most important consideration ($d_i + r_i$ is the highest) is the financial ecological environment (b_2) for the requirements of financial center modernization development. On the other hand, the credit market (c_1) is the criteria with the least impact on the other criteria ($d_i + r_i$ is the lowest) for financial center modernization. Financial industry development policy (a_1) has the maximum value of all criteria, indicating that this criterion has the greatest direct impact on others ($d_i - r_i$ is the highest); whereas, allocation of financial resources (a_3) is the criterion most easily influenced by other criteria ($d_i - r_i$ is the lowest).

Table 5. The sum of the influences given and received on the perspectives and criteria

Perspectives/Criteria	Row sum (d_i)	Column sum (r_i)	$d_i + r_i$	$d_i - r_i$
Government policy (*A*)	1.787	1.543	3.329	0.244
Financial industry development policy (a_1)	1.301	1.216	2.517	0.084
Financial supervision and regulation (a_2)	1.265	1.247	2.512	0.018
Allocation of financial resources (a_3)	1.193	1.296	2.489	–0.102
Financial infrastructure and safety (*B*)	1.602	1.637	3.239	–0.035
Financial infrastructure (b_1)	1.543	1.498	3.041	0.045
Financial ecological environment (b_2)	1.654	1.654	3.308	–0.000
Credit systems (b_3)	1.569	1.668	3.237	–0.098
Electronic financial and information safety (b_4)	1.639	1.586	3.225	0.053
Financial service (*C*)	1.528	1.682	3.210	–0.154
Credit market (c_1)	1.099	1.169	2.268	–0.070
Financial structure (c_2)	1.217	1.189	2.406	0.027
National financial market trading platform (c_3)	1.177	1.134	2.311	0.043
Financial institutions and human resources (*D*)	1.450	1.505	2.955	–0.055
Large financial institutions (d_1)	1.394	1.372	2.766	0.022
New financial institutions (d_2)	1.410	1.381	2.791	0.028
Listed financial enterprises (d_3)	1.266	1.269	2.535	–0.003
Financial employees' morality (d_4)	1.227	1.275	2.501	–0.048

A significant causal relationship can be observed among the four perspectives. The values of $d_i - r_i$ for A (government policy) are positive, meaning that this perspective affects other perspectives. On the other hand, the values of $d_i - r_i$ for perspective B (financial infrastructure and safety), perspective C (financial service), and perspective D (financial institutions and human resources) are negative, implying that these perspectives are influenced by another perspectives (government policy). Based on these findings, decision-makers can easily identify priorities for improvement from among complex criteria.

The data computed from the second stage through DEMATEL was combined with DANP, and the dynamic relationship was obtained among the criteria. However, in order to find the weight of each criterion, the regional financial center modernization model must be structured using DANP. The DEMATEL-based un-weighted super-matrix is obtained by using the Eqs. (10), (11), and (12), as shown in Table 6. The weighted super-matrix (Table 7) is calculated from Eqs. (8), (14), and (15) to reflect the degrees of influence exerted by the various dimensions. The limiting power of the weighted super-matrix is used to form a long-term stable condition, and represents the weights of various criteria (global weights), as listed in Table 8. This result, obtained via the DANP method, is applied to the modified VIKOR method by determining each criterion performance score.

Table 6. Un-weighted super-matrix $\boldsymbol{W}$ based on DANP for financial center modernization elements

Criteria	a_1	a_2	a_3	b_1	b_2	b_3	b_4	c_1	c_2	c_3	d_1	d_2	d_3	d_4
a_1	0.289	0.341	0.343	0.323	0.326	0.327	0.324	0.324	0.328	0.322	0.329	0.324	0.324	0.319
a_2	0.347	0.297	0.352	0.333	0.338	0.333	0.338	0.334	0.330	0.332	0.330	0.332	0.336	0.341
a_3	0.364	0.362	0.305	0.344	0.337	0.340	0.339	0.341	0.342	0.346	0.341	0.344	0.340	0.339
b_1	0.240	0.234	0.241	0.206	0.241	0.242	0.244	0.235	0.235	0.236	0.235	0.236	0.235	0.232
b_2	0.260	0.260	0.258	0.266	0.229	0.270	0.269	0.260	0.259	0.255	0.259	0.259	0.256	0.263
b_3	0.257	0.262	0.256	0.269	0.272	0.228	0.271	0.259	0.258	0.256	0.260	0.259	0.258	0.263
b_4	0.244	0.244	0.245	0.259	0.258	0.259	0.215	0.245	0.247	0.253	0.246	0.246	0.250	0.243
c_1	0.334	0.342	0.336	0.333	0.340	0.341	0.337	0.300	0.354	0.347	0.337	0.337	0.340	0.334
c_2	0.338	0.341	0.339	0.339	0.340	0.338	0.337	0.356	0.304	0.363	0.343	0.348	0.340	0.342
c_3	0.327	0.317	0.325	0.328	0.320	0.321	0.326	0.344	0.341	0.289	0.320	0.315	0.320	0.324
d_1	0.264	0.258	0.261	0.261	0.261	0.263	0.263	0.265	0.258	0.264	0.232	0.268	0.269	0.269
d_2	0.266	0.265	0.262	0.263	0.261	0.258	0.261	0.262	0.262	0.268	0.268	0.234	0.268	0.275
d_3	0.242	0.240	0.240	0.237	0.236	0.238	0.235	0.237	0.241	0.234	0.249	0.246	0.212	0.250
d_4	0.228	0.237	0.237	0.239	0.242	0.241	0.240	0.236	0.239	0.233	0.251	0.252	0.250	0.206

Table 7. Weighted super-matrix $\boldsymbol{W}^{\alpha}$ based on DANP for financial center modernization elements

Criteria	a_1	a_2	a_3	b_1	b_2	b_3	b_4	c_1	c_2	c_3	d_1	d_2	d_3	d_4
a_1	0.058	0.068	0.069	0.068	0.068	0.069	0.068	0.069	0.070	0.068	0.070	0.069	0.069	0.067
a_2	0.070	0.060	0.071	0.070	0.071	0.070	0.071	0.071	0.070	0.070	0.070	0.070	0.071	0.072
a_3	0.073	0.073	0.061	0.072	0.071	0.071	0.071	0.072	0.073	0.074	0.072	0.073	0.072	0.072
b_1	0.071	0.069	0.071	0.059	0.069	0.069	0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.069
b_2	0.077	0.077	0.076	0.076	0.066	0.077	0.077	0.077	0.077	0.076	0.077	0.077	0.076	0.078
b_3	0.076	0.078	0.076	0.077	0.078	0.065	0.078	0.077	0.077	0.076	0.078	0.077	0.077	0.078
b_4	0.072	0.072	0.073	0.074	0.074	0.074	0.062	0.073	0.073	0.075	0.073	0.073	0.078	0.072
c_1	0.077	0.079	0.077	0.077	0.078	0.077	0.078	0.065	0.077	0.076	0.077	0.077	0.078	0.077
c_2	0.078	0.078	0.078	0.078	0.078	0.078	0.077	0.078	0.066	0.079	0.079	0.080	0.073	0.078
c_3	0.075	0.073	0.075	0.075	0.074	0.075	0.075	0.075	0.074	0.063	0.073	0.072	0.072	0.074
d_1	0.072	0.071	0.071	0.071	0.071	0.072	0.072	0.072	0.070	0.072	0.061	0.070	0.071	0.071
d_2	0.073	0.072	0.071	0.072	0.071	0.071	0.071	0.072	0.071	0.073	0.070	0.061	0.070	0.072
d_3	0.066	0.066	0.066	0.065	0.065	0.065	0.064	0.065	0.066	0.064	0.065	0.064	0.056	0.065
d_4	0.062	0.065	0.065	0.065	0.066	0.066	0.066	0.064	0.065	0.064	0.066	0.066	0.065	0.054

Table 8. Influential weights of DANP for each criterion obtained by $\lim_{z\to\infty}(\boldsymbol{W}^{\alpha})^{z}$

Criteria	a_1	a_2	a_3	b_1	b_2	b_3	b_4	c_1	c_2	c_3	d_1	d_2	d_3	d_4
Weights (DANP)	0.068	0.070	0.071	0.069	0.076	0.076	0.073	0.076	0.077	0.073	0.071	0.071	0.065	0.064

The modified VIKOR method is employed to evaluate the overall performance gaps (or so-called regret) of regional financial center modernization. The score of each criterion and the total average gap ($S_k = \sum_{j=1}^{n} w_j r_{kj}$) in China's regional financial center modernization are acquired by taking the global weights from the DANP influential weights in order to multiply the gap (r_{kj}). The average performance value can be obtained from the performance values $(f_{kj} \mid j = 1,2,...,n)$ and relative gaps ($r_{kj} = \left| f_j^{aspire} - f_{kj} \right| \Big/ \left| f_j^{aspire} - f_j^{worst} \right| \mid j = 1,2,...,n$) of all criteria, as illustrated in Table 9. With the help of these performance values, decision-makers are able to find solutions for all types of problems for each perspective, or the perspective of the criteria as a whole. The government policy (*A*) has the highest performance value of 7.218, as compared with the other dimensions. On the other hand, financial institutions and human resources (*D*) have the lowest performance value of 6.91, as compared with the other dimensions. It can be seen that the total average performance is 7.079; whereas, the total average gap from the aspired value is 0.292, indicating that the distance from the optimal level exceeds 29.2%.

Table 9. Integrated index of financial center modernization dimensions and criteria

	Local weights	Global weights	Performance	Relative gaps
Government policy (*A*)	0.209		7.218 (1)	0.278 (4)
Financial industry development policy (a_1)	0.325	0.068	7.833	0.217
Financial supervision and regulation (a_2)	0.333	0.070	6.444	0.356
Allocation of financial resources (a_3)	0.342	0.071	7.389	0.261
Financial infrastructure and safety (*B*)	0.294		7.103 (3)	0.290 (2)
Financial infrastructure (b_1)	0.235	0.069	6.944	0.306
Financial ecological environment (b_2)	0.259	0.076	7.556	0.244
Credit systems (b_3)	0.259	0.076	7.000	0.300
Electronic financial and information safety (b_4)	0.247	0.073	6.889	0.311
Financial service (*C*)	0.227		7.122(2)	0.288 (3)
Credit market (c_1)	0.337	0.076	6.611	0.339
Financial structure (c_2)	0.341	0.077	7.111	0.289
National financial market trading platform (c_3)	0.322	0.073	7.667	0.233
Financial institutions and human resources (*D*)	0.270		6.910 (4)	0.309 (1)
Large financial institutions (d_1)	0.261	0.071	6.167	0.383
New financial institutions (d_2)	0.262	0.071	6.778	0.322
Listed financial enterprises (d_3)	0.239	0.065	7.333	0.267
Financial employees' morality (d_4)	0.238	0.064	7.444	0.256
Total average performance	–	–	**7.079**	–
Total average gap	–	–	–	**0.292**

3.3. Discussion

Figure 1 shows the causal relationship of the perspectives and criteria, as measured in this study, for the promotion of China's regional financial center modernization, as illustrated by systematics of INRM. Based on the degree of the dimension effect, improvements should be made according to the following order: government policy (*A*), financial infrastructure and safety (*B*), financial institutions and human resources (*D*), and financial service (*C*). The results indicate that government policy has the greatest immediate network effects on the other perspectives, and can help resolve multiple problems simultaneously. The findings imply that government policy on regional financial center modernization should be deepened for China, and the quality and effectiveness of service can be improved as a result. The main regular environment of a regional financial center should provide participants with a relative financial incentive system, and efficiently implement it. In order to enhance the financial market's operational efficiency and promote regional economy growth, the optimization financial policy is the best means to accomplish regional financial center modernization.

Within an individual dimension, the influences of network relationships of certain criteria also have the same effects; namely the financial industry development policy (a_1), electronic financial and information safety (b_4), national financial market trading platform (c_3), and new financial institutions (d_2). These are the major influential factors within each dimension, im-

plying that they have priority in improvements, and provide a higher level model for regional financial center modernization. In terms of the result in the dimension of government policy (A); it suggests that government should promote a financial incentive system or a tax abatement program to strengthen regional financial center modernization development. This finding is similar to Deng *et al.* (2012), meaning tax incentives not only attract FDI, but also improve domestic firms' performance, which is conducive to regional economic development. In terms of the result in the dimension of financial infrastructure and safety (*B*), we understand that enhancing electronic financial transaction information security is important for decision makers to manage financial infrastructure and safety. The dimension of financial service (*C*) implies that the trade center of financial assets and foreign exchange market have to be set up first. Furthermore, in the financial institutions and human resources (*D*) aspect, this finding showed that building a variety of new financial institutions is the most effective method for advancing regional financial center modernization. The details, from the perspectives of individual or overall point of view, of the framework for sustainable development are as shown in Table 10.

In addition, the overall performance value is 7.079, as shown in Table 9, with 10 as the aspiration level. The total average gap indicating room for improvement is 0.392. Table 9 also shows the performance value between each dimension/criterion and the gap value from the aspired level, and the descending rank of each dimension's performance is, as follows: $A\_C\_B\_D$. It is notable that financial institutions and human resources (*D*) (gap value is 0.309) are the least confident dimensions, implying an acute shortage of financial institutions and human resources. Among the 15 criteria (Table 6), the "large financial institutions (d_1)" for China's regional financial center modernization development has the largest gap value. This shows that "large financial institutions (d_1)" has the greatest room for improvement, implying that is the most unsatisfying and unachievable criterion, and must be increased. This information gives decision-makers a reference in planning for the enhancement of performance and comprehensive regional financial center modernization development. Administrative authority can better comprehend the current strengths and weakness through this information before launching a priority improvement strategy.

Table 10. The financial center modernization implementation improvement plan

Items	Strategy (Sequence of improvement priority)
F1: Influential network of dimensions of DEMATEL	$A\_B\_D\_C$
F2: Influential network of criteria within individual dimensions	*A*: $(a_1)\_(a_2)\_(a_3)$ $(a_2)\_(a_3)$ *B*: $(b_4)\_(b_1)\_(b_2)\_(b_3)$ $(b_1)\_(b_2)\_(b_3)$ $(b_2)\_(b_3)$ *D*: $(d_2)\_(d_1)\_(d_3)\_(d_4)$ $(d_1)\_(d_3)\_(d_4)$ $(d_3)\_(d_4)$ *C*: $(c_3)\_(c_2)\_(c_1)$ $(c_2)\_(c_1)$

Conclusions

This research proposes an improvement strategy for Guangzhou regional financial center modernization, which may serve as reference for the government to evaluate the development of modernization. A new decision model is constructed by integrating DEMATEL, DANP, and modified VIKOR methods, to illustrate the inter-relationship between the influential factors. Here, DEMATEL is mainly used to construct the INRM and weighted super matrix, DANP is used to resolve the inter-dependency and feedback relationship, and the modified VIKOR method is employed to integrate the performance gaps of each criterion within each dimension and overall. Based on the degree of the effect and impact, consideration should be given, as follows: government policy, financial infrastructure and safety, financial institutions and human resources, and financial service. Among the fourteen criteria, the financial industry development policy is critical, and most likely to influence the other rules, and thus, is the first priority for improvement. A sequence is made on the basis of dimension performance in descending order, as follows: government policy, financial service, financial infrastructure and safety, and financial institutions and human resources. According to this finding, financial institutions and human resources have the biggest gap from the aspired/desired level. The implications of these results for management and improvement strategies are illustrated in Table 10. In short, this study not only selected an appropriate regional financial center modernization development strategy, but also determined how to improve the gaps to achieve the aspired levels of determinants to enhance future performance.

The regional financial centers are set for more than 20 cities in China, thus, competition is intense. Local governments can promote their competitiveness by improving their modernization facilities, and enhancing their operational efficiency and quality through the results herein. The research methodology discussed herein is capable of dealing with complex issues related to the development of regional financial center modernization. Not only does this research have profound implications for responsible authorities, but even more important, it proposes a feasible and adequate development strategy for regional financial center modernization, which can assist the government in its shortcomings regarding improvements to the development of modernization.

Although this paper establishes a new model to evaluate regional financial center modernization effectiveness, some interesting points may be worth investigating in future research studies. The modified VIKOR in assessment to integrates each criterion into each dimension, and becomes a "non-additive type" (or "super-additive type") in the real world situation. However, this study still used the additive type in integrating each criterion into each dimension, and the "fuzzy integral" was used to solve "non-additive type" problem that integrates each criterion into each dimension. Thus, this better suits practical problems. The evaluation criteria were selected from a review of the literature on financial center modernization. However, the cloud computing industry is booming in recent years that has resulted in changes of the financial environment, and the relevant factors that may affect the development of the regional financial center modernization. Perhaps they may be important influential factors that should be considered in evaluating the impact of financial center modernization in future studies. Other methodologies can be used to identify other possible criteria, such as longitudinal studies. The number of expert samples can be increased in order to enhance the reliability of the results.

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APPENDIX

Appendix A: Experts' characteristics in practical experience

Category	No.	Job title
Government officials from the Guangdong office, China Banking Regulatory Commission (At least 10 years work experience on financial center development)	1	Chief of Department of State-owned Bank Supervision
	2	Chief of Department of Policy Banks and Postal Savings Bank Supervision
	3	Chief of Department of Non-bank Financial Institutions
	4	Chief of Supervision Department of Foreign Financial Institutions Supervision
	5	Chief of Department of Banking Innovation and Supervision
	6	Chief of Department of Banking Information Technology Supervision
	7	Chief of XX Branch, the Guangdong office
	8	Chief of XX Branch, the Guangdong office
	9	Chief of XX Branch, the Guangdong office
	10	Chief of XX Branch, the Guangdong office
	11	Chief of XX Branch, the Guangdong office
	12	Chief of XX Branch, the Guangdong office
Presidents or managers from financial institutions (More than 15 years of work experience)	13	Manager of XX Branch, XX Bank
	14	Manager of XX Branch, XX Bank
	15	Manager of XX Branch, XX Bank
	16	President of XX Bank
	17	President of XX Bank
	18	Chief of strategy office, XX Bank
	19	Chief of investment office, XX Bank
	20	Chief of investment office, XX Securities Corporation
	21	Manager of XX Securities Corporation
	22	Manager of XX Securities Corporation
Scholars of finance-related departments (At least 10 years of research experience on financial center development)	23	Professor of Department of Accounting
	24	Professor of Department of Finance and Investment
	25	Professor of Department of Finance and Investment
	26	Professor of Department of Finance
	27	Professor of Department of Management Science
	28	Professor of Department of Business Administration
	29	Senior Researcher
	30	Senior Researcher

Appendix B: Questionnaire

The second step questionnaire

Improving China's Regional Financial Center Modernization Development Using a New Hybrid MADM Model

Good day! This is an academic research about "**Improving China's Regional Financial Center Modernization Development Using a New Hybrid MADM Model**". The purpose is to improve regional financial center modernization improvement strategies, as well as key factors related to performance evaluation.

As we are greatly impressed by your excellent accomplishment in this field, if we could have the honor of receiving your valuable opinions, the result and reliability of the study will be extremely benefited. The information you provide is for academic statistical analysis only, and will not be separately announced to the outside or transferred to other applications. Therefore, please fill out the answers at ease.

Your support will be a key to the successful completion of the study. We are looking forward to the benefits if would take the time to express your opinions to be taken as reference for this study. Please accept our most sincere gratitude. Thank you very much.

B1. Instructions for filling out the questionnaire

This questionnaire is divided into six parts:

1) Instructions for completion;
2) Descriptions of dimensions and criteria;
3) Method for completion;
   3.1) Comparison of the impact of the four dimensions;
   3.2) Comparison of the impact of the 14 standards;
   3.3) Performance evaluation of the 14 standards;
4) Personal data.

B2. Descriptions of dimensions and criteria

Dimension	Criteria	Descriptions
Government policy	Financial industry development policy	Including the financial incentive system, tax abatements, and tax credits for enterprises, as promoted by the Guangzhou government;
	Financial supervision and regulation	Financial administrative authorities monitoring financial transactions and maintaining financial market stability;
	Allocation of financial resources	The central and local governments inject funds into the financial sector.

Dimension	Criteria	Descriptions
Financial infrastructure and safety	Financial infrastructure	Include convenient transportation and communication, and good capital flow environment;
	Financial ecological environment	Refers to the legal system, social honesty, and credit, the accounting and auditing standards, the intermediary service system, and the relationship between banks and firms;
	Credit systems	Build division and enterprise credit systems; establish financial credit infrastructure and systems; construct credit records, credit evaluation, credit monitoring, credit information disclosure and penalization systems, etc.;
	Electronic financial and information safety	Enhance electronic financial transaction information security.
Financial service	Credit market	Find a perfect credit market, such as loan institutions to SMEs;
	Financial structure	Whether or not Guangzhou financial industry (banking, insurance and security) development is unbalanced;
	National financial market trading platform	Establish a national financial market trading platform, such as the Guangzhou trade center in financial assets and foreign exchange market.
Financial institutions and human resources	Large financial institutions	Establish global and domestic influential financial institutions or introduce foreign financial institutions;
	New financial institutions	Set up a variety of new financial institutions;
	Listed financial enterprises Financial employees' morality	Increase the number of finance-related companies listed in Guangzhou. The quality and morality of financial professionals include CEO, managers, and staff.

B3. Method for completion

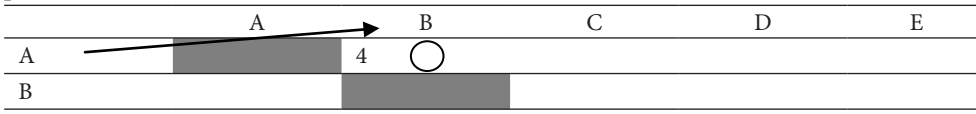
To complete the survey method and description, as follows:

Respond to the level of importance and performance of each criterion, according to experts' opinions in practical experience; enter the scales specified for importance (choosing important criteria) and performance (using evaluation and improvement) by natural language.

B3.1. Comparison of the impact of the four dimensions

Instructions for completing the index: **No impact (0)**; **Low impact (1)**; **Medium impact (2)**; **High impact (3)**; **Very high impact (4).**

Example: The impact of A on B is very high, thus, "4" is filled out at the corresponding position.



Real case description

1) The impact of **government policy** on **financial infrastructure and safety** is **"Very high"**; therefore, **4** is entered in the box;
2) The impact of **financial infrastructure and safety** on **financial institutions and human resources** is **"High"**; therefore, **3** is entered in the box.

Dimensions	Government policy	Financial infrastructure and safety	Financial service	Financial institutions and human resources
Government policy		4		
Financial infrastructure and safety				3
Financial service				
Financial institutions and human resources				

Please complete the comparison level of four dimensions in the following table

Dimensions	Government policy	Financial infrastructure and safety	Financial service	Financial institutions and human resources
Government policy				
Financial infrastructure and safety				
Financial service				
Financial institutions and human resources				

Instructions for completion of the index: **No impact (0); Low impact (1); Medium impact (2); High impact (3); Very high impact (4).**

B3.2. Comparison of the impact of the 14 standards (Please complete the compared levels of 14 criterions in the following table)

Criteria	Financial industry development policy	Financial supervision and regulation	Allocation of financial resources	Financial infrastructure	Financial ecological environment	Credit systems	Electronic financial and information safety	Credit market	Financial structure	National financial market trading platform	Large financial institutions	New financial institutions	Listed financial enterprises	Financial employees' morality
Financial industry development policy														
Financial supervision and regulation														
Allocation of financial resources														
Financial infrastructure														
Financial ecological environment														
Credit systems														
Electronic financial and information safety														
Credit market														
Financial structure														
National financial market trading platform														
Large financial institutions														
New financial institutions														
Listed financial enterprises														
Financial employees' morality														

Instructions for completing the index: **No impact (0)**; **Low impact (1)**; **Medium impact (2)**; **High impact (3)**; **Very high impact (4).**

B3.3. Survey of the improvability level of the performance evaluation factors

Criteria	Considering the performance evaluation of the standard, enter 0–10 **Very unimportant ← 0,1,2,…,8,9,10 → Very important** Very unimportant · Unimportant · Moderate · Important · Very important 0 1 2 3 4 5 6 7 8 9 10
Financial industry development policy	
Financial supervision and regulation	
Allocation of financial resources	
Financial infrastructure	
Financial ecological environment	
Credit systems	
Electronic financial and information safety	
Credit market	
Financial structure	
National financial market trading platform	
Large financial institutions	
New financial institutions	
Listed financial enterprises	
Financial employees' morality	

B4. Basic personal data

1. Gender: ☐Male ☐Female
2. Education Level: ☐College ☐University ☐Master ☐Ph.D.
3. Service Unit: _____ . 4. Service Dept.: _____ . 5. Job Title: _____.
6. Age: ☐ Under 30 years old (including) ☐ 31~35 years old ☐ 36~40 years old ☐ 41~50 years old ☐ Over 50 years old

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He was an Associate Professor at Chiao Tung University, Taiwan, from 1977 to 1981, a Research Associate at Argonne National Laboratory from July 1981 to January 1982, a Visiting Professor in the Department of Civil Engineering at the University of Maryland, College Park, from August 1989 to August 1990, a Visiting Professor in the Department of Engineering and Economic System, Energy Modeling Forum at Stanford University, from August 1997 to August 1998, a Professor at Chaio Tung University from 1981 to 2003, and a Chair Professor at Chiao Tung University. He got National Distinguished Chair Professor (Highest Honor offered by the Ministry of Education Affairs, Taiwan) and Distinguished Research Fellow (Highest Honor Offered by NSC, Taiwan) from 2000. His current research interests include statistics, multivariate analysis, network, routing and scheduling, multiple criteria decision making, fuzzy theory, hierarchical structure analysis for applying to technology management, energy, environment, transportation systems, transportation investment, logistics, location, urban planning, tourism, technology management, electronic commerce, global supply chain, etc. He got Highly Cited Paper (March 13, 2009) ESI "Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS" as published in the "EUROPEAN JOURNAL OF OPERATIONAL RESEARCH" on 16th July 2004, 156(2): 445–455, has been recently identified by Thomson Reuters' Essential Science Indicators SM to be one of the most cited papers in the field of Economics.

He has got the MCDM Edge worth-Pareto Award by International Society on Multiple Criteria Decision Making (June 2009), has got the Pinnacle of Achievement Award 2005 of the world, and had got the national distinguished chair professor and award (highest honor offered) of the Ministry of Education Affairs of Taiwan and three times of distinguished research award and two times of distinguished research fellow (highest honor offered) of National Science Council of Taiwan. Fellow IEEE Member (From September 30, 2002). He organized a Taiwan affiliate chapter of the International Association of Energy Economics in 1984 and he was the Chairman of the Tenth International Conference on Multiple Criteria Decision Making, 19–24 July 1992, in Taipei; the Co-Chairman of the 36th International Conference on Computers and Industrial Engineering, 20–23 June 2006, Taipei, Taiwan; the Chairman of the International Summer School on Multiple Criteria Decision Making, 2–14 July 2006, Kainan University, Taiwan. He is a member of IEEE, IAEE, ISMCDM, World Transport, the Operations Research Society of Japan, the Society of Instrument and Control Engineers Society of Japan, the City Planning Institute of Japan, the Behavior metric Society of Japan, the Japan Society for Fuzzy Theory and Systems; and participating many Society of Taiwan.