https://doi.org/10.1016/j.trd.2018.01.017

New Energy Vehicle in China for Sustainable Development: Analysis of Success Factors and Strategic Implications

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Abstract: The purpose of this study is to understand the effects of the influential factors that affect the sustainable development of new energy vehicle in China, investigate the cause-effect relationships among them, and propose some appropriate policies and efficacious measures for the policy-makers to promote its sustainable development. Interpretative Structuring Modeling was used to identify the critical factors affecting the sustainability of China's new energy vehicle industry and to find the potential relationships among the factors; subsequently, fuzzy Decision Making Trial and Evaluation Laboratory was employed to investigate the cause-effect relationships among the influential factors and to prioritize these factors. The results reveal that technological maturity, technological standards for new energy vehicles, and funds on R&D of new energy vehicles are the three most important driving factors for promoting the sustainable development of new energy vehicle industry of China. Some implications were also proposed for China's authority. The success factors and strategic implications of new energy vehicles in China were investigated in a multi-criteria analysis approach.

Keywords: New energy vehicle; Interpretative Structuring Modeling; Influential factors; DEMATEL

1. Introduction

China has achieved a significant progress on economy which attracts worldwide attentions, and one of the most distant achievements is the double digit growth of gross domestic production (GDP) (Hong et al., 2013). However, this also leads to many problems, i.e. energy security problems(Ren and Sovacool, 2014a; Wu, 2014) and environmental contaminations (Jiang et al., 2010; Ren et al., 2015b). To detail these, China's oil dependence rate reached 54.8% by the end of June 2011, the rate will contentiously grow in future, and almost 80% of the imported oil was transported from the Strait of Malacca as a strategic vulnerability of China which is a single chokepoint and has high risks for oil transportation (Zhang, 2011). The import rate of total consumed oil in China will reach to 76% by 2015 (BP, 2016). The greenhouse gas emission is the a severe typical environmental problem in China, the CO_2 emissions of China increased rapidly at the speed of 6% from 1990 to 2006 and reached 5.65 billion tons in 2006, and finally surpassed U.S. and became the largest CO_2 emitter (Hong et al., 2013; Jiang et al., 2010). The CO_2 emissions in China account to 25% of the total emissions (IEA, 2015), thus, energy consumption and greenhouse gas emissions become two of the most important concerns of China's authority.

The transport, especially passenger transport, has significant contribution to global energy consumption and greenhouse gas emissions (Zhou et al., 2013). Similarly in China, substantial increase of passenger and freight transport demand in China due to the rapid urbanization, industrialization, and burgeoning GDP has leaded to a sharply increase of energy consumption and greenhouse gas emissions in the past decades (He and Chen, 2013). Accordingly, energy-saving (especially refers saving fossil fuels) and emissions mitigation on national transport attracted more and more attentions from academic and China's authority (Li et al., 2013a).

It was estimated that China's private car ownership has reached 28.7 millions by 2007 which accounts for 66% of the total national civilian vehicles (Wang et al., 2013). There are 23.85 million new cars which were registered in China in 2015, and the car ownership reached 279 million (Xinhua News, 2016). The car ownership in China is very low, and there are only 25 cars per 1000 people in China whereas Europe has 600 cars per 1000 people, and the US has more than 700 cars per 1000 people. With the improvements of living standards of Chinese citizens, the demand of vehicles in China will continuously grow the future (Bambawale and Sovacool, 2011). It is apparent that large amount of energy consumption and greenhouse gas emissions due to transport are two severe problems in future of China. Thus, various measures and actions have been implemented to address these problems, i.e. developing public transport routes (Cao and Liang, 2012), fuel quality improvement, alternative fuels and advanced vehicles (Wu et al., 2010), and restricting the use of vehicles (Xiaoming et al., 2008), et al. Among these, the measure of developing advances vehicles, especially new energy vehicles has been regarded as one of the most promising scenarios for enhancing energy security, saving fossil fuels and alleviating greenhouse gas emissions (Gong et al., 2013; Liu and Kokko, 2013).

New energy vehicles refer to the four-wheel vehicles that use non-traditional fuels (bioethanol, liquid natural gas, biogas, and biodiesel), electric vehicles, battery electric vehicle, plug-in hybrid vehicle, and various hybrid types of these vehicles (Liu and Kokko, 2013). New energy vehicle industry has been received more and more attentions all over the world for its advantages of high potential for energy saving and emission mitigation (Cuma and Koroglu, 2015; Hannan et al., 2014; Li et al., 2014; Poullikkas, 2015; Raslavičius et al., 2015; Speidel and Bräunl, 2014). The development of new energy vehicle is the inevitable choice to China for achieving a low-carbon future, mitigating energy dependence, and completing economy transition (Yang et al., 2014). China has initiated new energy vehicles plans and projects (especially focusing on electric vehicles) since the late of 1990s, and China's authority took the new energy vehicle industry as a good opportunity to overtake the developed countries in automotive industry for the small technology- and industry gap between China and the developed countries (Hu et al., 2010). There are also various types of new energy vehicles in China such as pure electric vehicle, fuel cell vehicle, natural gas vehicle, and biofuel vehicle, etc. (Luo and Zhang, 2012). Among these new energy vehicles, battery electric vehicle and plug-in hybrid electric vehicle are the most popular in China and both of them have promising development potentials for promoting China's low-carbon transportation under the current conditions. The battery electric vehicle adopts electric motors and motor controllers rather than internal combustion engines for the propulsion of vehicle. The plug-in hybrid electric vehicle adopts the rechargeable batteries or some other energy storage device for propulsion, and these energy storage device can be recharged. However, China's new vehicle industry faces not only opportunities, but also challenges and obstacles, i.e. technology maturity, consumer acceptability, standards and regulations, et al (Zhou *et al*., 2013; Xu, 2014). Accordingly, more and more studies have been carried out to analyze the status of China's new vehicle industry and to propose some measures for promoting its development. For instance, Zhang and Hu (2013) used SWOT analysis to analyze the strengths, weaknesses, opportunities and threats of China's new energy vehicle industry and provided some recommendations to enhance the competitiveness for the new energy automotive industry. Li *et al*. (2013b) investigated the existed problems in China's new energy vehicle industry through a systematic analysis, and also proposed some measures for improving this industry. Yuan *et al*. (2015) presented a comprehensive and critical review of the policy framework for China's new energy vehicle industry, analyzed significant challenges that hinder its development, and proposed some suggestions for future development. All these studies are beneficial to the stakeholders/decision-makers in China to take efficacious measures for promoting the development of new energy vehicle industry of China. However, it is also important to analyze the sustainability of new energy vehicle industry for a sustainable future. In order to fill this gap, this study aims at analyzing all the factors in economic, environmental, social-political, and technological aspects that influence the sustainability of China's new energy vehicle (mainly refers to battery electric vehicle and plug-in hybrid electric vehicle) industry, investigating the cause-effect relationships among the influential factors, prioritizing these factors, and proposing some valuable implications for promoting the sustainable development of China's new energy industry.

Besides the first part (Introduction), this study is organized as follows: Part 2 presents the methodology by applying it on China's new energy vehicle industry, Interpretative Structuring Modeling has been used to identify the factors affecting the sustainability of China's new energy vehicle industry and to find the potential relationships among the factors; subsequently, fuzzy Decision Making Trial and Evaluation Laboratory has been employed to investigate the cause-effect relationships among the influential factors and to prioritize these factors; then, the results have been discussed in details; according to the results, some implications have been proposed for China's authority in Part 3; finally, this study has been concluded in Part 4.

2. Methodology

Interpretative Structuring Modeling (ISM) and fuzzy Decision Making Trial and Evaluation Laboratory (DEMATEL) were combined to investigate the success factors affecting China's new energy vehicle industry and the complex relationships among these factors in this study. ISM was used to determine the influential factors and to identify the potential relationships among the influential factors, then, fuzzy DEMATEL was employed to investigate the cause-effect relationships among the influential factors and to prioritize these factors in term of their relative importance on promoting the sustainable development of China's new energy vehicle industry.

2.1 ISM for identifying potential relationships among the influential factors

Interpretative Structuring Modeling (ISM) can help the decision-makers to develop a map for describing the complex relationships among multiple factors involving in a complex situation through computer-aided learning process (Kannan et al., 2009). This methodology developed by Warfield in 1974 (Warfield, 1974a, b) has been successfully and widely used for understanding the complex relationships among the factors in the complex problems or issues, i.e. analysis of the interactions among barriers of smart grid technologies adoption (Luthra et al., 2014), green supply chain management (Diabat and Govindan, 2011; Mathiyazhagan et al., 2013), barriers analysis of implementing solar power installations (Ansari et al., 2013), and barriers analysis for energy saving (Wang et al., 2008), et al. Based on these, it could be deduced that ISM is also able to investigate the complex relationships among the factors affecting the sustainable development of new energy vehicle industry in China. The procedures of ISM methodology for identifying the potential relationships among the factors affecting the sustainable development of China's new energy vehicle industry consists of four main steps: (i) influential factors determination; (ii) structural self-interaction matrix determination; (iii) initial reachability matrix determination; and (iv) final reachability determination (Kannan et al., 2009). It is worth pointing put the main purpose of this study using ISM on the factors affecting the sustainable development of China's new energy vehicle industry is to identify the potential relationships among the influential factors. And the results of the potential relationships among the factors affecting the sustainable development of new energy vehicle industry in China determined by ISM will be transferred to fuzzy Decision

Making Trial and Evaluation Laboratory (DEMATEL) for investigating the cause-effect relationships among the factors and prioritizing these factors.

The procedures of ISM methodology for identifying the potential relationships among the factors affecting the sustainable development of China's new energy vehicle industry has been specified based on Refs. (Ansari *et al*., 2013; Diabat and Govindan, 2011; Kannan *et al*., 2009; Luthra *et al*., 2014; Mathiyazhagan *et al*., 2013; Wang *et al*., 2008; Warfield, 1974a, b):

Step 1: Determining the influential factors of sustainable new energy vehicle industry in China. Firstly, all the peer-reviewed paper, books and reports concerning new vehicles industry of China in the databases of China National Knowledge Infrastructure (CNKI), Web of Knowledge, and Google Scholar have been collected to find the influencing factors, and a focus group meeting has been held to determine the influencing factors through brainstorm. The objective of this step is to investigate all the influencing factors that affect the sustainable development of new vehicle industry in China. There are total 21 factors in four aspects including economic, environmental, social-political, and technological aspects have been obtained. The results have been presented as follows:

● Economic aspect

(1) Low cost for the purchasement of vehicles (F_1)

New energy vehicles perform better on functions compared with the traditional vehicles; however, the difference on the price compared to the traditional vehicles is also very large, and new energy vehicles cannot be competitive due to the high cost for purchasement, thus, low cost for the purchasement of vehicles is quite important for attracting the interests of the consumers (Zhang, 2014).

(2) Low cost for fuel consumption (F_2)

Although "energy-saving" concept of new energy vehicles is widely advertised, there is also a big gap between the actual performances of new energy vehicles on energy-saving and the ideal goal due to routes and road conditions, and the new energy vehicles do not have dominant advantages compared with the traditional vehicles (Ma and Wu, 2014). Moreover, the production cost for the fuels of new energy vehicle cannot be neglected as the production process also has to consume large amount of the traditional fossil fuels, i.e. the production of bioethanol (Ren et al., 2013c), and all the four major bioethanol companies in China have to rely on national subsidies as the sale price is at least 35 Yuan RMB (1 Yuan RMB≈0.1625 USD) lower than the total cost for 1 t bioethanol (Zhang et al., 2008). Thus, the production cost for fuels of new energy vehicle is also urgently needed to be lowered.

(3) Low cost for repair and maintenance (F_3)

The high failure rate of new energy vehicles is one of the most severe challenges that hinder the development of this industry as high failure rate leads to frequent repair and maintenance and further cause high cost for repair and maintenance (Ma and Wu, 2014). Thus, low cost for repair and maintenance is urgently needed.

(4) Mature commercial mode of new energy vehicle industry (F_4)

Mature commercial mode refers to develop new businesses and business models to provide the infrastructure, component, vehicle, and services necessary to enable a good ecosystem of new energy vehicle (Mehndiratta, 2011). Especially, a mature commercial mode of new energy vehicle industry also means that the running of this industry does not need to reply on subsidies from the government in long term. Moreover, a mature commercial mode can also fully take the effects of market for industrialization and scale-up of new energy vehicle, and further for servicing the public and improving the livelihood (Li, 2012).

(5) Governmental financial support (F_5)

Governmental financial support refer the subsidies and tax exemption measures drafted or issued by the China's authority or local governments for financial support to the consumers or manufacturers in the industry chain of new energy vehicle to promote the development of new energy vehicle industry. For instance, the news from the meeting of State Council on July 9th declared that China cancelled the 10 percent vehicle purchase tax on new energy vehicles (i.e. electrical vehicle) (China Briefing, 2014; Ministry of Industry and information Technology of China, 2014). And this measure aims at encouraging Chinese consumers to new energy vehicles instead of the traditional vehicles.

(6) Low production cost of new energy vehicle (F_6)

Due the lack of some key technologies, some core components of electrical vehicles such as batteries, motors, and electronic control systems have be imported, and these three main components account for almost 70% of the total production, that is the reasons why the costs of electrical vehicles in China are so high (Yong-hua, 2012). Low production cost of new energy vehicle is the key for the industrialization and commercialization of this industry in large scale.

(7) Funds on R&D of new energy vehicles (F_7)

Funds on R&D of new energy vehicles refer the available funds set special for the activities concerning research and demonstration of new energy vehicles.

● Environmental aspect

(1) Low environment pollution of new energy vehicle (F_8)

The traditional vehicles highly depend on the fossil fuels, especially petroleum, that are not environmental-friendly, so environmental contamination (i.e. greenhouse gases and haze-fog phenomenon) was caused due to large amount of energy consumption in the past decades, thus, the new energy vehicles are regarded as a promising option for resolving the environmental problems caused by the traditional vehicles as they use non-traditional fuels (i.e. electricity, hydrogen, and methane, et al.) as power sources or adopt new types of automotive powertrain systems and control systems to form advanced automotive systems (Zhang, 2014).

(2) Fuel efficiency (F_9)

Fuel efficiency represents the consumed fuel of the new energy vehicles for per mileage, and it can be obviously measured accordingly the ratio between the amounts of the fuel consumed by the new energy vehicles to the amount of that consumed by the traditional vehicles for the same distance. If the ratio is greater than 1, then, the new energy vehicle is less fuel-efficient than the traditional vehicle; On the contrary, the new energy vehicle is more fuel-efficient than the traditional vehicle when the ratio is less than 1. Fuel efficiency is an important criterion to measure the potential of the new energy vehicles on energy performance, and energy-saving means environment protection, especially under the condition that the fuels used in the new energy vehicles produced from some other nonrenewable energy sources (i.e. hydrogen used in hydrogen fuel cell vehicles produced from natural gas and electricity used in electrical vehicles produced from coal-based power plant).

(3) Greenness of energy sources (F_{10})

Many clean energy resources, i.e. electricity, hydrogen, and methane can be used as the power sources of new energy vehicles. However, the environment impacts of these energy sources should be considered in its life cycle as the service life of new energy vehicle is short compared to the traditional vehicles. Thus, the greenness of energy sources should be studied in their life cycle perspective (Zhang et al., 2009).

(4) Recycling of battery (F_{11})

The waste battery of new energy vehicles would cause serious environmental problems, i.e. pollution on soil and underground water, if they are not well treated.

● Social-Political aspect

(1) High social acceptability (F_{12})

High price of new energy vehicles is one of the biggest obstacles to popularize it in China as the price of new energy vehicle is much higher than gasoline vehicles even the subsidies are considered (Yuan et al., 2015). The acceptability of Chinese people on new energy vehicles is the key for the booming of new energy vehicle industry in China.

(2) Policies, regulations and strategies (F_{13})

As a burgeoning emerging-industry, the policies, regulations and strategies that can efficaciously support the industrialization and commercialization of new energy industry are urgently needed (Lu and Chen, 2014). Moreover, the policies, regulations and strategies in national level are quite useful for promoting the development of new energy vehicle industry. For instance, it has been found that establishing hydrogen development prior strategy in China is the most effective and important measure to promote hydrogen economy in China (Ren et al., 2015a). The booming of hydrogen economy is the foundation of hydrogen fuel cell vehicle as a typical new energy vehicle. As for national policies, regulations and strategies for new energy vehicles of China, there are two typical ones: the implementation of National High-tech R&D Program (863 Plan) in 2001 to initiate Electric Automobile Projects as national project (Yong-hua, 2012) and the issue of "New Energy Vehicle Production Entrance Guideline" in 2007 (Chen et al., 2008; National Development and Reform Commission, China, 2007). All these similar policies, regulations and strategies drafted in the past years have vigorously stimulated the development of new energy vehicle industry in China. Thus, more and more policies and national strategies are need in China for promoting the development of new energy vehicle industry.

(3) Service after-sale (F_{14})

Service after-sale refers to all the services for the consumers after-sale, i.e. technological guides, responses to the complaints of the consumers, and phone/home visits, etc.

(4) Convenience for maintenance (F_{15})

Convenience for maintenance refers to the accessibility of maintenances for new energy vehicles. This criterion has significant effect on the perceptions of consumers as all the consumers hate the difficulties on maintenance.

(5) Technological standards for new energy vehicles (F_{16})

The technological standards for new energy vehicle industry in China are not consistent and perfect as different automotive companies adopt different production technologies and production philosophies, so it lacks the common standards for the assessment of new energy vehicles; moreover, it also lacks the common regulations for the technical standards of some equipment of new energy vehicles, i.e. the size of battery, operational life pan of battery, and charge spot, etc. (Zhang, 2014).

(6) Brand images (F_{17})

China does not have very famous national brands for the traditional vehicles, and it is a good opportunity for China to develop famous national own brands for new energy vehicles as the new energy vehicle industry is a burgeoning emerging-industry all over the world (Liang et al., 2014). However, the potential consumers in China do not have very good impressions on national brand of new energy vehicles due to the doubt on the quality and safety (Yong-hua, 2012). Moreover, the brand images have dominant influences on the perceptions of the consumers, so building national brand images is quite important.

● Technological aspect

(1) Safety (F_{18})

New energy vehicles have quite different fuel feeding systems and driving modes compared to the traditional vehicles, and these leads to new hidden dangers, i.e. fire disaster and self-ignition (Zhang et al., 2014).

(2) Mileage and horsepower (F_{19})

The mileage and horsepower are two of the most criteria to measure the performances of new energy vehicles. However, the new energy vehicles are relatively weak in these two aspects. Taking the mileage as an example, the mileage of the electrical vehicles is 80-100 km, and it has a large distance to the expectation of the consumers which is 200 km (Ma and Wu, 2014).

(3) Infrastructure (F_{20})

The industrialization of new energy vehicles depends not only on the advanced technologies, but also the mature industry chain, especially the downstream supporting infrastructure for fuel charging, and the construction of infrastructure in China is not so well-developed as some other developed countries, i.e. German, United States, and Japan (Yuan et al., 2015). However, most of the potential consumers of new energy vehicles in China are the first time to buy cars, and they prefer the vehicles that have perfect infrastructure for fuel charging (Yong-hua, 2012).

(4) Technological maturity (F_{21})

Technological maturity is quite important for new energy vehicle industry as it is essential for the manufacture of automotive products, and also for guaranteeing the whole performances of new energy vehicles to be better than the traditional vehicles (Luo and Zhang, 2012). However, China still lacks some core technologies for the manufacture of new energy vehicle, i.e. energy storage devices, the compatibility between high energy and high power in battery, the stability of fuel cell stack, motor, and system integration technologies (Yuan et al., 2015; Yang and Kong,2014).

Step 2: Determining the structural self-interaction matrix (SSIM) (Mukhtar and Schiffauerova, 2016). 'V', 'A', 'X', and 'O' have been used to represent the relationship between each pair of strategic measures, and

V: The i-th factor will affect the j-th factor;

A: The j-th factor will be influenced by the i-th factor;

X: The i-th factor and the j-th factor will affect each other; and

O: No direct relationship between the i-th factor and the j-th factor.

For instance, low cost for fuel consumption (F_2) has been regarded to affect high social acceptability (F_{12}), so V' was put in cell (S_2, S_{12}). Governmental financial support (F_5) has been regarded to be affected by policies, regulations and strategies (F_{13}), so 'A' was put in cell (S_5, S_{13}). High social acceptability (F_{12}) and policies, regulations and strategies (F_{13}) have been regarded to be interacted, so 'X' was put in cell (S_{12}, S_{13}). While 'O' was put in the corresponding place if there is no relation between two barriers, such as the elements in cell (S_3, S_{14}) and cell (S_5, S_{16}). In a similar way, the other elements in the structural self-interaction matrix can also be determined, and the results have been presented in Table 1.

Step 3: Determining the initial reachability matrix (IRM). The structural self-interaction matrix (in Table 1) has been transformed into the initial reachability matrix according to the following rules (Thirupathi and Vinodh, 2016):

- If the element in the cell (i,j) of the structural self-interaction matrix is V, the elements in the cell (i,j) and cell (j,i) of the initial reachability matrix should be 1 and 0, respectively.

● If the element in the cell (i,j) of the he structural self-interaction matrix is A, the elements in the cell (i,j) and cell (j,i) of the initial reachability matrix should be 0 and 1, respectively.

● If the element in the cell (i,j) of the structural self-interaction matrix is X, both the elements in the cell (i,j) and cell (j,i) of the initial reachability matrix should be 1.

● If the element in the cell (i,j) of the he structural self-interaction matrix is O, both the elements in the cell (i,j) and cell (j,i) of the initial reachability matrix should be 0.

For instance, 'V' is the element of cell (S_2, S_{12}) in the structural self-interaction matrix, then, the element of cell (S_2, S_{12}) in the initial reachability matrix should be 1, and the element of cell (S_{12}, S_2) in the initial reachability matrix should be 0. 'A' is the element of cell (S_5, S_{13}) in the structural self-interaction matrix, then, the element of cell (S_{13}, S_5) in the initial reachability matrix should be 1, and the element of cell (S_5, S_{13}) in the initial reachability matrix should be 0. 'X' is the element of cell (S_{12}, S_{13}) in the structural self-interaction matrix, then, both the element of cell (S_{12}, S_{13}) and that of cell (S_{13}, S_{12}) in the initial reachability matrix should be 1. 'O' is the element of cell (S_3, S_{14}) in the structural self-interaction matrix, then, both the element of cell (S_3, S_{14}) and that of cell (S_{14}, S_3) in the initial reachability matrix should be 0. Similarly, all the elements in the initial reachability matrix could be determined, as presented in Table 2.

Step 4: Determining the final reachability matrix. The final reachability matrix can be obtained through transitivity (Metha *et al.*, 2014; Ren and Sovacool, 2014). The transitivity of the contextual relation is a basic assumption in ISM, and it represents that if the i-th factor affects the j-th factor, and the j-th fator affects the k-th factor, then the i-th factor is regarded to affect the k-th factor. For instance, the elements of cell (S_5, S_1) and cell (S_1, S_4) equal 1, and it means that governmental financial support (F_5) affects low cost for the purchasement of vehicles (F_1), and low cost for the purchasement of vehicles (F_1) affects mature commercial mode (F_4), so it could be deduced that governmental financial support (F_5) affects mature commercial mode (F_4), then, cell (S_5, S_4) in the final reachability matrix. Based on this rule, the final reachability can be obtained, as presented in Table 3.

Thus, the potential relationships among the 21 influential factors affecting the sustainable development of China's new energy vehicle industry have been obtained. Although ISM has the ability to determine the driving power and dependence of each element in the complex problem, and to partition the element into different hierarchies that have been illustrated in many studies (Chandramowli et al., 2011; Jia et al., 2015; Kumar et al., 2014), this methodology cannot appropriately consider the relationship between of each pair of elements/factors in the complex problem as the binary variables (0 and 1) can only measure whether each pair of elements/factors have relationship or not. In other words, how one element/factor affects another cannot be incorporated in ISM. Accordingly, some hybrid methodologies have been developed by combining ISM with some other methods. For instance, Lee et al. (2011) developed a model by combining ISM, fuzzy analytic network process (FANP), and benefits, opportunities, costs and risks (BOCR) to analyze strategic products for photovoltaic silicon thin-film solar cell power industry in which BOCR has been used to determine the evaluation criteria, ISM has been employed to determine the interdependence among the criteria, and then FANP has been used to determine the overall priorities of product strategies based on the relationships among the criteria determined by ISM. Similarly, ISM and fuzzy DEMATEL combined in this study, and fuzzy DEMATEL has been conducted in Section 2.2 based on the results determined by ISM.

2.2 Fuzzy DEMATEL for investigating the cause-effect relationships and prioritizing the influential factors

Decision Making Trial and Evaluation Laboratory (DEMATEL) method was developed by the Science and Human Affairs Program of the Battelle Memorial Institute of Geneva between 1972 and 1976 for the complicated and intertwined problems (Gabus and Fontela, 1973; Fontela and Gabus, 1976; Shieh et al., 2010). DEMATEL has the ability to directly compare the relationships and interdependences between each pair of elements/factors in the complex problem, and to use a matrix to determine the direct/indirect causal relationships and the influence levels between each pair of variables (Lee et al., 2010). This method has been widely used in many files for investigating the cause-effect relationships among the elements/factors in the complex problems and identifying the critical elements/factors that have significant influences on the problem. For instance, Hsu et al. (2013) used the DEMATAL approach to recognize the influential criteria of carbon management in green supply chain for improving the overall performance of suppliers in terms of carbon management. Lin et al. (2011) employed the DEMATEL method to explore the core competences and cause-effect of the factors influencing the competences of the integrated circuit design service company. Zhou et al. Zhou et al. (2011) identified the critical success factors in emergency management by using DEMATEL. Ren et al. (2013a) identified the critical criteria and cause-effect relationships among the criteria that have significant influences on the sustainability of hydrogen supply chain. All these problems studied by using DEMATEL are complex problems that are similar to the sustainable development of China’s new energy vehicles, thus, DEMATEL method has been used in this study. The crisp numbers, i.e. the numbers 0-4 representing “No influence (0)”, “Low influence (1)”, “Medium influence (2)”, “High influence (3)”, and “Very high influence (4)” respectively to describe the relationships among the elements/factors in the complex problem (Falatoonitoosi et al., 2013). However, it is usually difficult for the users to use the crisp numbers to describe the relative influence of one factor on another, because there are usually various types of subjectivity, vagueness, and ambiguity existing in human judgments (Afgan et al., 2008). And fuzzy set theory has enables the users to overcome this obstacle, as used in many studies (Ren et al., 2013b; Ren and Sovacool, 2014a). Accordingly, DEMETEL has been extended by combining fuzzy set theory, and various fuzzy DEMATEL methods have been developed and used (Baykasoğlu et al., 2013; Chang et al., 2011a; Chang et al., 2011b; Chou et al., 2012; Ren and Sovacool, 2014b; Yeh and Huang, 2014).

The conduction of fuzzy DEMATEL on analyzing the cause-effect relationships among the factors affecting the sustainable development of China's new energy vehicle and prioritizing these factors has been presented as follows based on Refs. (Chang et al., 2011b; Chou et al., 2012; Ren and Sovacool, 2014b):

Step 1: Determining the direct-influenced matrices using linguistic terms. The purpose of this step is to determine the direct influencing relationships among these factors that have relationships. The stakeholders/decision-makers are invited to participate in the decision-making on the direct-influenced matrices. They are usually two most popular ways to execute this decision-making: (i) inviting the stakeholders/decision-makers to attend a colloquium; (ii). Phone and email communications. The organizer will introduce the purpose of this decision-making, the influenced factors and the methodology for determining the direct influence between any two factors by slides or some other ways. In addition, some published works related to the topic (i.e. papers, books, and technical reports), will be provided to them.

In this study, multiple experts including professors whose research interests consist of renewable energy and sustainability, PhD students whose dissertation involves industrial ecology, and engineers who are skilled in automobile industry and management science are invited in the focus group meeting to investigate the complex relationships among 21 (i=1,2,…,21) factors that influence the sustainable development of new vehicle industry in China, and a coordinator was nominated in this colloquium. Subsequently, the experts were asked to use the linguistics including "No influence (N)", "Low influence (L)", "Medium influence (M)", "High influence (H)", and "Very high influence (VH)" (as presented in Table 4) to describe the influence of one factor on another.

For instance, it could be deduced that low cost for the purchasement of vehicles (F_1) affects mature commercial mode (F_4), high social acceptability (F_{12}), and policies, regulations and strategies (F_{13}) according to the results determined by ISM (see Table 3), and all the experts presented their opinions on 'How do you think about the influence of low cost for the purchasement of vehicles (F_1) on the following factors?' by filling the designed questionnaire, an example has been presented in Table 5. One expert held the view that the influence of low cost for the purchasement of vehicles (F_1) on High social acceptability (F_{12}) should be 'Very high influence (VH)', and the symbol '√' is then put in the corresponding place, as shown in Table 5. After gathering all the responses of the experts, the coordinator is responsible for organizing a final discussion to achieve a consensus among the experts for alleviating the inaccuracy caused by the lack of knowledge and incorrect judgments. Then, the assessment determined by the stakeholder/decision-makers yields a 21×21 matrix, as presented in Table 6.

Step 2: Transforming the direct-influenced matrices using linguistic terms into fuzzy direct-influenced matrices. The objective of this step is to transform the linguistic terms into triangular fuzzy numbers according to Table 4. Thus, "No influence (N)", "Low influence (L)", "Medium influence (M)", "High influence (H)", and "Very high influence (VH)” in Table 6 can be transformed into (0,0,0.25), (0,0.25,0.50), (0.25,0.50,0.75), (0.50,0.75,1.00), and (0.75,1.00,1.00), respectively. Then, the fuzzy direct-influenced matrix can be obtained, as presented in Table 7. It is a 21×21 fuzzy matrix, as presented in in Eq.1.

$$\left\{\tilde{X}\right\}_{21\times21}=\begin{bmatrix}(0,0,0.25) & \tilde{x}_{12} & \cdots & \tilde{x}_{1n}\\ \tilde{x}_{21} & (0,0,0.25) & \cdots & \tilde{x}_{2n}\\ \vdots & \vdots & \ddots & \vdots\\ \tilde{x}_{n1} & \tilde{x}_{n2} & \cdots & (0,0,0.25)\end{bmatrix} \tag{1}$$

$$\tilde{x}_{ij}=\left(x_{ij}^{L},x_{ij}^{M},x_{ij}^{U}\right), i=1,2,\cdots,21;\ j=1,2,\cdots,21 \tag{2}$$

where $\tilde{x}_{ij}$ represents the element of cell (i, j) in the fuzzy direct-influenced matrix, and x_{ij}^{L} , x_{ij}^{M} and x_{ij}^{U} are the three elements of the triangular fuzzy number $\tilde{x}_{ij}$.

Step 3: Normalizing the fuzzy direct-influenced fuzzy matrix. The normalized fuzzy direct-relation matrix $\tilde{D}$ could be obtained by Eqs.3-5.

$$r=\max_{i=1,2,\cdots,n}\left(\sum_{j=1}^{n}x_{ij}^{U}\right) \tag{3}$$

$$\tilde{D}=\left[\tilde{d}_{ij}\right]_{n\times n} \tag{4}$$

$$\tilde{d}_{ij}=\left(d_{ij}^{L},d_{ij}^{M},d_{ij}^{U}\right)=\left(\frac{x_{ij}^{L}}{r},\frac{x_{ij}^{M}}{r},\frac{x_{ij}^{U}}{r}\right) \tag{5}$$

where $\tilde{D}$ is the normalized initial direct-relation matrix, and it is assumed that at least one i such that $\sum_{j=1}^{n}a_{ij}^{U}<r$.

According to Table 7 and Eq.3, it can be obtained that $r=17$, then, the normalized fuzzy direct-relation matrix $\tilde{D}$ can be obtained by Eqs. 6-7. In other words, the normalized fuzzy direct-relation matrix $\tilde{D}$ can be determined after all the elements in the fuzzy direct-influenced matrix $\left\{\tilde{X}\right\}_{21\times21}$ divided by 17.

$$\tilde{D} = \left\{ \tilde{X} \right\}_{21\times 21} \Big/ 17 \quad (6)$$

$$\tilde{d}_{ij} = \left(d_{ij}^{L}, d_{ij}^{M}, d_{ij}^{U} \right) = \left(\frac{x_{ij}^{L}}{17}, \frac{x_{ij}^{M}}{17}, \frac{x_{ij}^{U}}{17} \right) \quad (7)$$

Step 4: Computing the total-relation fuzzy matrix. The powers of $\tilde{D}$ represent the indirect effects between any factors and satisfies $\lim_{w\to\infty} \tilde{D} = 0$, and the total relation matrix $\tilde{T}$ could be calculated by Eqs.8-15.

$$\tilde{T} = \left[\tilde{t}_{ij} \right]_{21\times 21} = \lim_{w\to\infty} (\tilde{D} + \tilde{D}^2 + \cdots + \tilde{D}^w) \quad (8)$$

$$\tilde{t}_{ij} = \left(t_{ij}^{L}, t_{ij}^{M}, t_{ij}^{U} \right) \quad (9)$$

$$\left[t_{ij}^{L} \right]_{21\times 21} = D^L \times (I - D^L)^{-1} \quad (10)$$

$$D^L = \begin{bmatrix} d_{11}^L & d_{12}^L & \cdots & d_{1n}^L \\ d_{21}^L & 0 & \cdots & d_{2n}^L \\ \vdots & \vdots & \ddots & \vdots \\ d_{n1}^L & d_{n2}^L & \cdots & d_{nn}^L \end{bmatrix} \quad (11)$$

$$\left[t_{ij}^{M} \right]_{21\times 21} = D^M \times (I - D^M)^{-1} \quad (12)$$

$$D^M = \begin{bmatrix} d_{11}^M & d_{12}^M & \cdots & d_{1n}^M \\ d_{21}^M & d_{22}^M & \cdots & d_{2n}^M \\ \vdots & \vdots & \ddots & \vdots \\ d_{n1}^M & d_{n2}^M & \cdots & d_{nn}^M \end{bmatrix} \quad (13)$$

$$\left[t_{ij}^{U} \right]_{21\times 21} = D^U \times (I - D^U)^{-1} \quad (14)$$

$$D^U = \begin{bmatrix} d_{11}^U & d_{12}^U & \cdots & d_{1n}^U \\ d_{21}^U & d_{22}^U & \cdots & d_{2n}^U \\ \vdots & \vdots & \ddots & \vdots \\ d_{n1}^U & d_{n2}^U & \cdots & d_{nn}^U \end{bmatrix} \quad (15)$$

where $\tilde{T}$ represents the total relation matrix and I is the identity matrix.

According to Eqs.10-15 and the normalized fuzzy direct-relation matrix $\tilde{D}$ obtained by Eq.6 and Eq.7, then, the three matrices including $\left[t_{ij}^{L} \right]_{21\times 21}$, $\left[t_{ij}^{M} \right]_{21\times 21}$ and $\left[t_{ij}^{U} \right]_{21\times 21}$ can be obtained, as presented in Tables 8-10. Then, $\tilde{T}$ can be determined according to Eqs.8-15 and Tables 8-10, it is worth pointing out that all the elements in this matrix are fuzzy numbers. For instance, the element of cell (i, j) is $\tilde{t}_{ij} = \left(t_{ij}^{L}, t_{ij}^{M}, t_{ij}^{U}\right)$, and t_{ij}^{L}, t_{ij}^{M}, and t_{ij}^{U} are the elements of cell (i,j) in $\left[t_{ij}^{L}\right]_{21\times21}$, $\left[t_{ij}^{M}\right]_{21\times21}$, and $\left[t_{ij}^{U}\right]_{21\times21}$, respectively.

Step 5: Obtaining the cause-effect relationship map. The objective of this step it to identify the cause-effect relationships among the influencing factors.

As for the matrix $\tilde{T}$, the sum of all the elements the i-th line represents the total effect that directly and indirectly exerted by the i-th factor , as presented in Eq.16.

$$\tilde{R}_i = \sum_{j=1}^{n} \tilde{t}_{ij} \tag{16}$$

where $\tilde{R}_i = \left(R_i^{L}, R_i^{M}, R_i^{U}\right)$ is a triangular fuzzy number

While the sum of all the elements the i-th column represents the total effect including direct and indirect effects on the j-th factor, as presented in Eq.17.

$$\tilde{C}_j = \sum_{i=1}^{n} \tilde{t}_{ij} \tag{17}$$

where $\tilde{C}_j = \left(C_j^{L}, C_j^{M}, C_j^{U}\right)$ is a triangular fuzzy number

Thus, the sum $\tilde{R}_i + \tilde{C}_i$ represents the total effects given and received by the i-th factor, and it can be used as a measure of the relative importance and the power of the i-th factor in the complex system. The difference $\tilde{R}_i - \tilde{C}_i$, so-called “relation”, represents the net effects that contributed by the i-th factor to the whole system, and it is a measure of the independence and the driving force of the i-th factor. It worth pointing out that both $\tilde{R}_i + \tilde{C}_i = \left(RC_i^{L+}, RC_i^{M+}, RC_i^{U+}\right)$ and $\tilde{R}_i - \tilde{C}_i = \left(RC_i^{L-}, RC_i^{M-}, RC_i^{U-}\right)$ are also triangular fuzzy numbers, as presented in

Table 11.

where RC_i^{L+}, RC_i^{M+}, and RC_i^{U+} are the three elements of fuzzy number $\tilde{R}_i + \tilde{C}_i$, and RC_i^{L-}, RC_i^{M-}, and RC_i^{U-} are the three elements of fuzzy number $\tilde{R}_i - \tilde{C}_i$.

Then, $\tilde{R}_i + \tilde{C}_i$ and $\tilde{R}_i + \tilde{C}_i$ can be defuzzied to their crisp values through Eq.18 andEq.19, respectively.

$$\tilde{N}_{\tilde{R}_i+\tilde{C}_i}^{def} = L^+ + \Delta^+ \times \frac{(RC_i^{M+} - L^+)(\Delta^+ + RC_i^{U+} - RC_i^{M+})^2(R - RC_i^{L+}) + (RC_i^{U+} - L^+)^2(\Delta^+ + RC_i^{M+} - RC_i^{L+})^2}{(\Delta^+ + RC_i^{M+} - RC_i^{L+})(\Delta^+ + RC_i^{U+} - RC_i^{M+})^2(R^+ - RC_i^{L+}) + (RC_i^{U+} - L^+)(\Delta^+ + RC_i^{M+} - RC_i^{L+})^2(\Delta^+ + RC_i^{U+} - RC_i^{M+})}$$

(18)

where $\tilde{N}_{\tilde{R}_i+\tilde{C}_i}^{def}$ represents the defuzzied value of the fuzzy number $\tilde{R}_i + \tilde{C}_i = \left(RC_i^{L+}, RC_i^{M+}, RC_i^{U+}\right)$, $L^+ = \min\limits_{i=1,2,\cdots,21}\left(RC_i^{L+}\right)$, $R^+ = \max\limits_{i=1,2,\cdots,21}\left(RC_i^{U+}\right)$, and $\Delta^+ = R^+ - L^+$

$$\tilde{N}_{\tilde{R}_i-\tilde{C}_i}^{def} = L^- + \Delta^- \times \frac{(RC_i^{M-} - L^-)(\Delta^- + RC_i^{U-} - RC_i^{M-})^2(R^- - RC_i^{L-}) + (RC_i^{U-} - L^-)^2(\Delta^- + RC_i^{M-} - RC_i^{L-})^2}{(\Delta^- + RC_i^{M-} - RC_i^{L-})(\Delta^- + RC_i^{U-} - RC_i^{M-})^2(R - RC_i^{L-}) + (RC_i^{U-} - L^-)(\Delta^- + RC_i^{M-} - RC_i^{L-})^2(\Delta^- + RC_i^{U-} - RC_i^{M-})}$$

(19)

where $\tilde{N}_{\tilde{R}_i-\tilde{C}_i}^{def}$ represents the defuzzied value of the fuzzy number $\tilde{R}_i - \tilde{C}_i = \left(RC_i^{L-}, RC_i^{M-}, RC_i^{U-}\right)$, $L^- = \min\limits_{i=1,2,\cdots,21}\left(RC_i^{L-}\right)$, $R^- = \max\limits_{i=1,2,\cdots,21}\left(RC_i^{U-}\right)$, and $\Delta^- = R^- - L^-$

Accordingly, $\tilde{R}_i + \tilde{C}_i$ and $\tilde{R}_i - \tilde{C}_i$ in Table 11 can be defuzzied into $R_i + C_i$ and $R_i - C_i$, as presented in Table 12 and Table 13, respectively.

2.3 Discussion

Accordingly to Ref. (Chang et al., 2011b; Chou et al., 2012; Ren and Sovacool, 2014b), the values of $R_i + C_i\left(i-1,2,\cdots,21\right)$ represents the relative importance and power of the influencing factors, thus, the prior sequence of these factors can be determined, as presented in Table 12. It is apparent that policies, regulations and strategies (F_{13}) is the most, followed by high social acceptability (F_{12}), technological maturity (F_{21}), mature commercial mode of new energy vehicle industry (F_4), technological standards for new energy vehicles (F_{16}), brand images (F_{17}), funds on R&D of new energy vehicles (F_7), low environment pollution of new energy vehicle (F_8), financial support (F_5), recycling of battery (F_{11}), fuel efficiency (F_9), greenness of primary energy sources (F_{10}), low production cost of new energy vehicle (F_6), infrastructure (F_{20}), convenience for use and maintenance (F_{15}), safety (F_{18}), mileage and horsepower (F_{19}), low cost for the purchasement of vehicles (F_1), low cost for repair and maintenance (F_3), service after-sale (F_{14}), and low cost for fuel consumption (F_2).

Meanwhile, the group category of each factor can be determined according to the values of $R_i - C_i \left(i - 1, 2, \cdots, 21\right)$, and if $R_i - C_i$ is positive, the i-th factor belongs to the cause group, and it means that this factors plays a driving role in the whole system. While $R_i - C_i$ is negative, the i-th factor belongs to the effect group, and it means that this factor plays a passive role in the whole system. Thus, all the 21 influencing factors can be categorized, as presented in Table 13. And low cost for repair and maintenance (F_3), financial support (F_5), low production cost of new energy vehicle (F_6), funds on R&D of new energy vehicles (F_7), fuel efficiency (F_9), greenness of primary energy sources (F_{10}), recycling of battery (F_{11}), service after-sale (F_{14}), convenience for use and maintenance (F_{15}), technological standards for new energy vehicles (F_{16}), safety (F_{18}), infrastructure (F_{20}), and technological maturity (F_{21})

belong to the cause group, and it means that these factors can be regarded as the root of the problems hindering the sustainable development of new energy vehicle industry in China. The other influential factors belong to the effect group.

As for the influential factors belonging to the cause group, their effect power in the whole systems can be deduced according to the values of $R_i + C_i$, and the larger the value of $R_i + C_i$ is, the more important the corresponding factor will be. Accordingly, if the value of $R_i + C_i$ is very great, it means that the corresponding factor is the core driving factor of solving the key problem and should be given priority for improving the whole system. Thus, it can be deduced that technological maturity (F_{21}), technological standards for new energy vehicles (F_{16}), and funds on R&D of new energy vehicles (F_7) are the three most important driving factors for promoting the sustainable development of new energy vehicle industry of China, followed by financial support (F_5), recycling of battery (F_{11}), and fuel efficiency (F_9), etc.

As for the influential factors belonging to the effect group, their dependence degree can also be determined according to the values of $R_i + C_i$, and the larger of the value of $R_i + C_i$, the more critical the corresponding factor will be, and it is the key factor required to be solved, however, it is not the root of the problem. While the smaller of the value of $R_i + C_i$, the less important the corresponding factor will be though it is an effect. Accordingly, policies, regulations and strategies (F_{13}) is the most critical factor in the effect group, followed by high social acceptability (F_{12}), mature commercial mode of new energy vehicle industry (F_4), and brand images (F_{17}), etc.

In order to completely understand the roles of these factors towards sustainable development of new energy vehicle industry of China, these factors have been divided into three regions by setting threshold (0.10) for the absolute values of $R_i - C_i$ with respect to the influential factors. In other words, the factors in the cause group belong to cause region if the corresponding values of $R_i - C_i$ are greater than 0.10; the factors in the effect group belong to effect region if the absolute values of $R_i - C_i$ are greater than 0.10; while the other factors belong to linkage region if the corresponding values of $R_i - C_i$ belong to the interval [-0.1, 0.1]. It is worth pointing out that the factors in the linkage region are unstable; in other words, they have high possibility to be transformed into effect group though the corresponding values of $R_i - C_i$ are greater than 0 or to be transformed into cause group though the corresponding values of $R_i - C_i$ are smaller than 0 if a small disturbance (i.e. vagueness and subjectivity of human judgments) on it. In addition, the core factors in each region can be identified according to the values of $R_i + C_i$, the critical factors in the cause group is the same with that discussed above; however only high social acceptability (F_{12}), mature commercial mode of new energy vehicle industry (F_4), and brand images (F_{17}) have been regarded as the critical factors in effect region as policies, regulations and strategies (F_{13}) has been regarded as the most critical factor in the linkage group (see Figure 1). Thus, policies, regulations and strategies can not only play an important role in the sustainable development of new energy vehicle industry, but also serve as a linkage between the factors in the cause region and that in the effect region.

3. Implications

According to the fuzzy DEMATEL analysis of the factors influencing the sustainable development of new energy vehicle industry in China, the following implications can be obtained for the stakeholders/decision-makers in China:

(1) The stakeholders/decision-makers in China should treat the influential factors unequally when allocating the limited funds for taking some actions to improve these factors. Among these factors, policies, regulations and strategies, high social acceptability, technological maturity, mature commercial mode of new energy vehicle industry, technological standards for new energy vehicles, brand images, funds on R&D of new energy vehicles are the most critical factors affecting the sustainable development of new energy vehicle industry in China, these seven factors should be given top priority for promoting the sustainable development of new energy vehicle industry in China. Low environment pollution in the whole life cycle of new energy vehicle, financial support, recycling of battery, fuel efficiency, greenness of primary energy sources, low production cost of new energy vehicle, and infrastructure are ranked in the second level according to their relative importance. The other factors are less important compared with these factors;

(2) Policies, regulations and strategies are the most important for promoting the sustainable development of new energy vehicle industry in China, thus, more policies and national strategies for supporting new energy vehicle industry are prerequisite. The policies, regulations and strategies for local license plate control exemption and local traffic restriction exemption for the users of new energy

vehicles should be drafted and implemented, and these can effectively attract more and more new drivers and increase the number of the owners of new energy vehicle. Accordingly, they can promote the development of new energy vehicle industry in China. In addition, the sharing economy which is emerging in China, and it can effectively promote the development of new energy vehicle industry by popularizing the sharing vehicle industry if it can get enough support from China's administration for complete regulation system, enough financial support system, and data availability. However, policies and national strategies are not independent but interacted with some other influential factors, thus, they may affect or be affected by some other influential factors, and it reveals that the stakeholders/decision-makers in China should draft appropriate policies and national strategies according to the actual conditions of China. In other words, the stakeholders/decision-makers in China should completely consider some other factors (i.e. economy development level, consumer perceptions, technological maturity) when drafting the policies and national strategies for promoting the sustainable development of new energy vehicle industry in China;

(3) Technological maturity, technological standards for new energy vehicles, and funds on R&D of new energy vehicles are the most important core factors for driving the sustainable development of new energy vehicle industry in China as they have significant influences on some key factors (i.e. policies and national strategies, high social acceptability, and mature commercial mode of new energy vehicle industry, etc.). In other words, these three factors are the essence of the

problems existed in China's new energy vehicle industry. Thus, the stakeholders/decision-makers in China should pay more attentions on improving technological maturity, drafting scientific technological standards for new energy vehicles, and investing more funds R&D of new energy vehicles.

(4) High social acceptability (F_{12}), mature commercial mode of new energy vehicle industry (F_4), and brand images (F_{17}) are also of vital importance for the sustainable development of new energy vehicle industry in China, but they are not the root of the problems hindering its development, and also not the key driving force as they are highly dependent on some other key factors in the cause group. However, these factors also show a clear direction for the stakeholders/decision-makers in future. The stakeholders/decision-makers should take some actions such as advertisement on new energy vehicles and education on the public to improve the social acceptability, foster a mature commercial mode of new energy vehicle industry by enhancing the perfection of the business ecosystem, and establishing excellent brand images for new energy vehicles through innovation and demonstration.

4. Conclusion

New energy vehicle industry is a new emerging driving force for the booming of China's economy, but it still stays in its infant stage due to many problems, i.e. high price, immaturity in technology, and consumer perceptions, etc. This study aims at analyzing the key success factors affecting the sustainable development of new energy vehicle industry of China and proposing some implications for the stakeholders/decision-makers to take effective measures and actions for promoting its development.

There are total 21 influential factors included in economic, environmental, social-political, and technological aspects that have been studied in this paper, and a hybrid ISM-Fuzzy DEMTEL method has been used to investigate the cause-effect relationships among these factors and to prioritize their roles in term of their relative importance. Interpretative structuring modeling has been used to identify the potential and possible relationships among the influential factors, and then, fuzzy Decision Making Trail and Evaluation Laboratory (DEMATEL) has been employed to study the effects of these factors on promoting the sustainable development of new energy vehicle industry. Finally, some implications for the stakeholders/decision-makers have been proposed according to the results.

The top experts of new energy vehicle industry have been invited to participate in the process of identifying the potential relationships among the factors, investigate the cause-effect relationships among the factors, and prioritize these influential factors to analyze the success factors and to propose some strategic measures for new energy vehicle industry of China. And the direct-influenced matrix using linguistic terms are determined through a focus group meeting. Actually, more and more experts can be invited to participate in this process, and each of them can determine a direct-influenced matrix using linguistic terms; then, an average fuzzy direct-influenced matrix can be used to determine the cause-effect relationships among the influential factors and to rank these factors. However, it is worth pointing out that the diverse options of different participants may lead to an inaccurate result due to the limitations of one's judgments. That is the reason why a focus group method has been used in this study as new energy vehicle industry is a new emerging-industry in China and it is difficult to ensure that each participant to have enough knowledge for making correct decisions. Thus, "an average fuzzy direct-influenced matrix" methodology can be employed only if all the participants have enough knowledge on new energy vehicle industry. Moreover, more influential factors are allowed to be added for investigation for new energy vehicle industry in China or some other regions.

Acknowledgements

This study was financially supported by The Start-up Grant of The Hong Kong Polytechnic University for New Employees (Project title: ***Multi-criteria Decision Making for More Sustainable Transportation*,** project account code: **1-ZE8W**).Great thanks to the experts from China's automotive industry for participation. We also sincerely thank the editors and the anonymous reviews for their valuable comments on this paper.

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Figures

Figure captions

Figure 1: Cause-effect relationship diagram of the factors affecting new energy vehicle industry of China

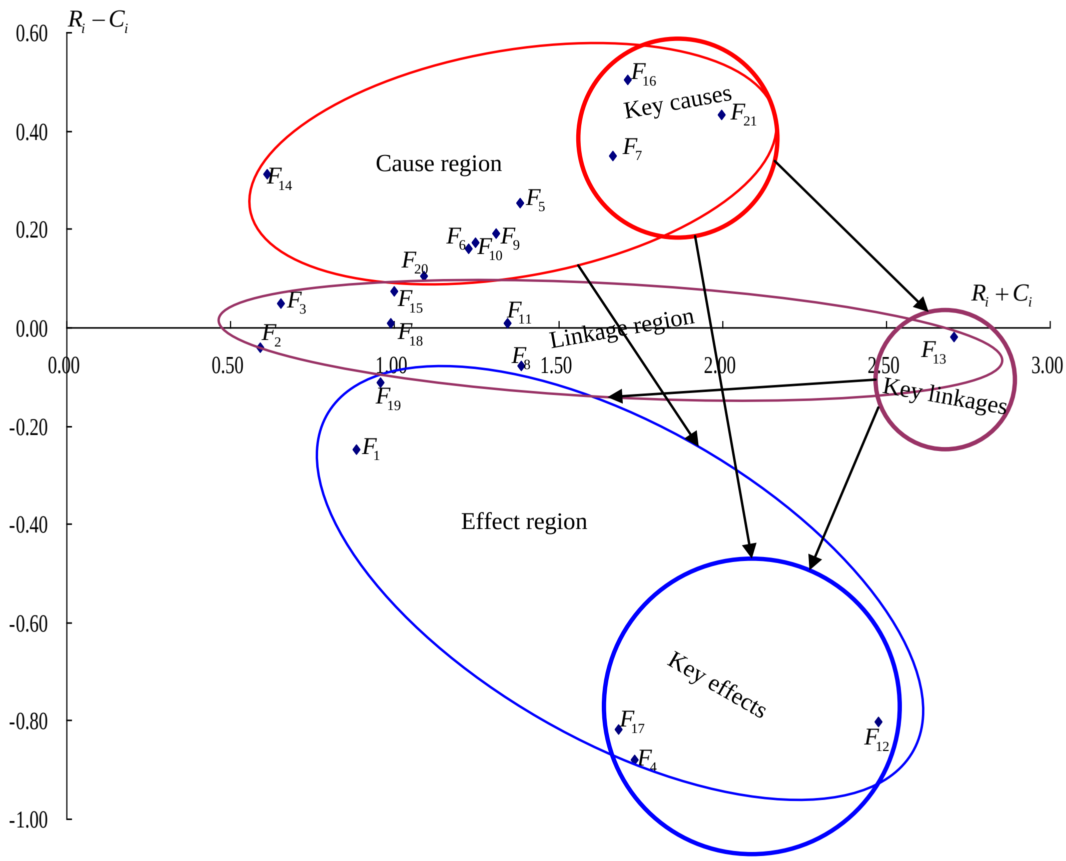

Figure 1: Cause-effect relationship diagram of the factors affecting new energy vehicle industry of China

Table

Table 1: Structural self-interaction matrix

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}	F_{21}
F_1	-	O	O	V	A	A	O	O	O	O	O	V	O	O	O	O	O	O	O	O	A
F_2		-	O	O	O	O	O	O	A	O	O	V	O	O	O	O	O	O	O	O	O
F_3			-	V	O	O	O	O	O	O	O	V	O	O	A	O	O	O	O	O	O
F_4				-	O	O	O	O	O	O	O	V	A	O	O	A	A	O	O	A	A
F_5					-	O	O	O	O	O	O	V	A	O	O	O	O	O	O	V	V
F_6						-	O	O	O	O	O	O	V	O	O	O	O	O	O	O	A
F_7							-	V	V	V	V	O	A	O	O	O	O	V	V	O	V
F_8								-	A	A	A	V	V	O	O	A	V	O	O	O	A
F_9									-	O	O	V	V	O	O	O	V	O	V	O	A
F_{10}										-	O	V	V	O	O	A	O	O	O	O	A
F_{11}											-	V	X	O	O	O	V	O	O	O	A
F_{12}												-	X	A	A	O	A	A	A	A	A
F_{13}													-	O	O	V	V	O	O	V	V
F_{14}														-	O	O	V	O	O	O	O
F_{15}															-	O	V	O	O	A	A
F_{16}																-	V	V	O	O	V
F_{17}																	-	A	A	O	A
F_{18}																		-	O	O	A
F_{19}																			-	O	A

F_{20}		-	O
F_{21}			-

Table 2: The initial reachability matrix

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}	F_{21}
F_1	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
F_2	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
F_3	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
F_4	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
F_5	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1
F_6	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
F_7	0	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	0	1	1	0	1
F_8	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	0	0	0
F_9	0	1	0	0	0	0	0	1	1	0	0	1	1	0	0	0	1	0	1	0	0
F_{10}	0	0	0	0	0	0	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0
F_{11}	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	1	0	0	0	0
F_{12}	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
F_{13}	0	0	0	1	1	0	1	0	0	0	1	1	1	0	0	1	1	0	0	1	1
F_{14}	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0
F_{15}	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0
F_{16}	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	1	1	1	0	0	1
F_{17}	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0
F_{18}	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0
F_{19}	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0
F_{20}	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0

F_{21}	1	0	0	1	0	1	0	1	1	1	1	1	0	0	1	0	1	1	1	0	1

Table 3: The final reachability matrix

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}	F_{21}
F_1	1	0	0	1	0	0	0	0	0	0	0	1	1^{*}	0	0	0	0	0	0	0	0
F_2	0	1	0	0	0	0	0	0	0	0	0	1	1^{*}	0	0	0	0	0	0	0	0
F_3	0	0	1	1	0	0	0	0	0	0	0	1	1^{*}	0	0	0	0	0	0	0	0
F_4	0	0	0	1	0	0	0	0	0	0	0	1	1^{*}	0	0	0	0	0	0	0	0
F_5	1	0	0	1^{*}	1	1^{*}	0	1^{*}	1^{*}	1^{*}	1^{*}	1	1^{*}	0	1^{*}	0	1^{*}	1^{*}	1^{*}	1	1
F_6	1	0	0	1^{*}	1^{*}	1	1^{*}	0	0	0	1^{*}	1^{*}	1	0	0	1^{*}	1^{*}	0	0	1^{*}	1^{*}
F_7	1^{*}	1^{*}	0	1^{*}	0	1^{*}	1	1	1	1	1	1^{*}	1^{*}	0	1^{*}	0	1^{*}	1	1	0	1
F_8	0	0	0	1^{*}	1^{*}	0	1^{*}	1	0	0	1^{*}	1	1	0	0	1^{*}	1	0	0	1^{*}	1^{*}
F_9	0	1	0	1^{*}	1^{*}	0	1^{*}	1	1	0	1^{*}	1	1	0	0	1^{*}	1	0	1	1^{*}	1^{*}
F_{10}	0	0	0	1^{*}	1^{*}	0	1^{*}	1	0	1	1^{*}	1	1	0	0	1^{*}	1^{*}	0	0	1^{*}	1^{*}
F_{11}	0	0	0	1^{*}	1^{*}	0	1^{*}	1	0	0	1	1	1	0	0	1^{*}	1	0	0	1^{*}	1^{*}
F_{12}	0	0	0	1^{*}	1^{*}	0	1^{*}	0	0	0	1^{*}	1	1	0	0	1^{*}	1^{*}	0	0	1^{*}	1^{*}
F_{13}	1^{*}	0	0	1	1	1^{*}	1	1^{*}	1^{*}	1^{*}	1	1	1	0	1^{*}	1	1	1^{*}	1^{*}	1	1
F_{14}	0	0	0	1^{*}	0	0	0	0	0	0	0	1	1^{*}	1	0	0	1	0	0	0	0
F_{15}	0	0	1	1^{*}	0	0	0	0	0	0	0	1	1^{*}	0	1	0	1	0	0	0	0
F_{16}	1^{*}	0	0	1	0	1^{*}	0	1	1^{*}	1	1^{*}	1^{*}	1^{*}	0	1^{*}	1	1	1	1^{*}	0	1
F_{17}	0	0	0	1	0	0	0	0	0	0	0	1	1^{*}	0	0	0	1	0	0	0	0
F_{18}	0	0	0	1^{*}	0	0	0	0	0	0	0	1	1^{*}	0	0	0	1	1	0	0	0
F_{19}	0	0	0	1^{*}	0	0	0	0	0	0	0	1	1^{*}	0	0	0	1	0	1	0	0
F_{20}	0	0	1^{*}	1	0	0	0	0	0	0	0	1	1^{*}	0	1	0	1^{*}	0	0	1	0

F_{21}	1	1^*	1^*	1	0	1	0	1	1	1	1	1	1^*	0	1	0	1	1	1	0	1

1^* means deducing by the “rule of transitivity”

Table 4: Linguistic terms and their equivalent fuzzy numbers

Linguistic terms	Abbreviations	fuzzy variables
No influence	N	(0,0,0.25)
Very low influence	L	(0,0.25,0.50)
Medium influence	M	(0.25,0.50,0.75)
High influence	H	(0.50,0.75,1.00)
Very high influence	VH	(0.75,1.00,1.00)

Reference: adapted from Chou *et al*. (2012)

Table 5: An example of the questionnaire for investigating the influence of low cost (F_1) on the other factors

How do you think about the influence of low cost for the purchasement of vehicles (F_1) on the following factors?

	N	L	M	H	VH
The influence of F_1 on mature commercial mode (F_4)			√		
The influence of F_1 on high social acceptability (F_{12})					√
The influence of F_1 on policy support and national strategies (F_{13})		√			

Reasons: the low cost for the purchasement of vehicles can effectively popularize the development of new energy vehicle industry in China, and the users of new energy vehicles are also pleased to the actions for lowering the costs for the purchasement of vehicles, thus, the influence of F_1 on high social acceptability (F_{12}) was recognized as "Very high influence (VH)",

Table 6: The direct-influenced matrix using linguistic terms

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}	F_{21}
F_1	N	N	N	M	N	N	N	N	N	N	N	VH	L	N	N	N	N	N	N	N	N
F_2	N	N	N	N	N	N	N	N	N	N	N	H	M	N	N	N	N	N	N	N	N
F_3	N	N	N	H	N	N	N	N	N	N	N	VH	M	N	N	N	N	N	N	N	N
F_4	N	N	N	N	N	N	N	N	N	N	N	VH	VH	N	N	N	N	N	N	N	N
F_5	VH	N	N	L	N	H	N	L	L	M	M	H	M	N	L	N	M	L	L	M	H
F_6	VH	N	N	VH	L	N	M	N	N	N	M	VH	L	N	N	L	VH	N	N	L	L
F_7	L	L	N	H	N	VH	N	H	H	H	H	M	L	N	M	N	M	H	H	N	VH
F_8	N	N	N	L	L	N	H	N	N	N	L	H	H	N	N	M	H	N	N	L	L
F_9	N	VH	N	M	L	N	M	L	N	N	L	H	H	N	N	L	H	N	H	L	L
F_{10}	N	N	N	L	L	N	M	VH	N	N	L	VH	VH	N	N	L	H	N	N	L	L
F_{11}	N	N	N	M	L	N	M	H	N	N	N	H	VH	N	N	L	L	N	N	L	M
F_{12}	N	N	N	M	VH	N	H	N	N	N	L	N	H	N	N	VH	H	N	N	M	H
F_{13}	H	N	N	VH	VH	M	H	VH	VH	H	H	H	N	N	M	VH	H	M	M	H	VH
F_{14}	N	N	N	VH	N	N	N	N	N	N	N	VH	H	N	N	N	VH	N	N	N	N
F_{15}	N	N	M	H	N	N	N	N	N	N	N	VH	VH	N	N	N	VH	N	N	N	N
F_{16}	M	N	N	H	N	M	N	VH	H	H	H	H	H	N	H	N	H	VH	H	N	H
F_{17}	N	N	N	VH	N	N	N	N	N	N	N	VH	M	N	N	N	N	N	N	N	N
F_{18}	N	N	N	H	N	N	N	N	N	N	N	VH	VH	N	N	N	VH	N	N	N	N
F_{19}	N	N	N	M	N	N	N	N	N	N	N	VH	M	N	N	N	VH	N	N	N	N
F_{20}	N	N	M	VH	N	N	N	N	N	N	N	VH	H	N	VH	N	H	N	N	N	N

F_{21}	VH	H	H	VH	N	VH	N	VH	VH	H	H	H	H	N	L	N	VH	VH	VH	N	N

Table 7: The fuzzy direct-influenced matrix ($\left\{\tilde{X}\right\}_{21\times21}$)

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}	F_{21}
F_1	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.00,1.00)	(0,0.25,0.50)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)
F_2	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0.25,0.50,0.75)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)
F_3	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.00,1.00)	(0.25,0.50,0.75)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)
F_4	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.00,1.00)	(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)
F_5	(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0.25,0.50)	(0,0.25,0.50)	(0.25,0.50,0.75)	(0.25,0.50,0.75)	(0.50,0.75,1.00)	(0.25,0.50,0.75)	(0,0,0.25)	(0,0.25,0.50)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0.25,0.50)	(0,0.25,0.50)	(0.25,0.50,0.75)	(0.50,0.75,1.00)
F_6	(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0.75,1.00,1.00)	(0,0.25,0.50)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.25,0.50,0.75)	(0.75,1.00,1.00)	(0,0.25,0.50)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0,0.25,0.50)
F_7	(0,0.25,0.50)	(0,0.25,0.50)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0,0.25)	(0.75,1.00,1.00)	(0,0,0.25)	(0.50,0.75,1.00)	(0.50,0.75,1.00)	(0.50,0.75,1.00)	(0.50,0.75,1.00)	(0.25,0.50,0.75)	(0,0.25,0.50)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0,0.25)	(0.25,0.50,0.75)	(0.50,0.75,1.00)	(0.50,0.75,1.00)	(0,0,0.25)	(0.75,1.00,1.00)
F_8	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0,0.25,0.50)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0.50,0.75,1.00)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0.25,0.50,0.75)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0,0.25,0.50)
F_9	(0,0,0.25)	(0.75,1.00,1.00)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0.25,0.50)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0.25,0.50)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0.50,0.75,1.00)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0.50,0.75,1.00)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0.25,0.50)	(0,0.25,0.50)
F_{10}	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0,0.25,0.50)	(0,0,0.25)	(0.25,0.50,0.75)	(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0.75,1.00,1.00)	(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0,0.25,0.50)
F_{11}	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0.25,0.50)	(0,0,0.25)	(0.25,0.50,0.75)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0,0.25,0.50)	(0,0,0.25)	(0,0,0.25)	(0,0.25,0.50)	(0.25,0.50,0.75)

F_{21}	F_{20}	F_{19}	F_{18}	F_{17}	F_{16}	F_{15}	F_{14}	F_{13}	F_{12}
(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0,0.25)
(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)
(0.50,0.75,1.00)	(0.25,0.50,0.75)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)
(0.75,1.00,1.00)	(0.75,1.00,1.00)	(0.25,0.50,0.75)	(0.50,0.75,1.00)	(0.75,1.00,1.00)	(0.50,0.75,1.00)	(0.50,0.75,1.00)	(0.75,1.00,1.00)	(0.75,1.00,1.00)	(0.25,0.50,0.75)
(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.00,1.00)	(0.75,1.00,1.00)
(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0,0.25)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0,0.25)
(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0.50,0.75,1.00)
(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0.75,1.00,1.00)	(0,0,0.25)
(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0.75,1.00,1.00)	(0,0,0.25)
(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0,0.25)
(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0.25,0.50)
(0.50,0.75,1.00)	(0.75,1.00,1.00)	(0.75,1.00,1.00)	(0.75,1.00,1.00)	(0.75,1.00,1.00)	(0.50,0.75,1.00)	(0.75,1.00,1.00)	(0.75,1.00,1.00)	(0.50,0.75,1.00)	(0,0,0.25)
(0.50,0.75,1.00)	(0.50,0.75,1.00)	(0.25,0.50,0.75)	(0.75,1.00,1.00)	(0.25,0.50,0.75)	(0.50,0.75,1.00)	(0.75,1.00,1.00)	(0.50,0.75,1.00)	(0,0,0.25)	(0.50,0.75,1.00)
(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)
(0,0.25,0.50)	(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0,0.25)
(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.00,1.00)	(0.75,1.00,1.00)
(0.75,1.00,1.00)	(0.50,0.75,1.00)	(0.75,1.00,1.00)	(0.75,1.00,1.00)	(0,0,0.25)	(0.50,0.75,1.00)	(0.75,1.00,1.00)	(0.75,1.00,1.00)	(0.50,0.75,1.00)	(0.50,0.75,1.00)
(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0,0.25)
(0.75,1.00,1.00)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0.25,0.50,0.75)	(0,0,0.25)
(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0.25,0.50,0.75)
(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0,0,0.25)	(0.50,0.75,1.00)	(0,0,0.25)	(0,0,0.25)	(0.75,1.00,1.00)	(0.50,0.75,1.00)

Table 8: The matrix $\left[t_{ij}^{L}\right]_{21\times21}$

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}	F_{21}
F_1	0.000274	5.99E-05	6.11E-05	0.015794	0.002098	0.00026	0.001423	0.000325	0.000276	0.000249	0.000253	0.045272	0.002278	0	0.00015	0.002103	0.001669	0.00024	0.000217	0.000764	0.001622
F_2	0.000692	9.21E-05	7.21E-05	0.001542	0.002052	0.000469	0.001436	0.000968	0.000889	0.000657	0.000664	0.03048	0.016025	0	0.000359	0.002066	0.001737	0.000448	0.000444	0.00095	0.001798
F_3	0.000828	0.000117	9.64E-05	0.031405	0.002852	0.000584	0.001982	0.001141	0.001041	0.000783	0.000792	0.046719	0.017924	0	0.000433	0.002869	0.002382	0.000556	0.000544	0.001256	0.002432
F_4	0.00183	0.00022	0.000158	0.003591	0.004118	0.001164	0.002927	0.002618	0.002428	0.001749	0.001766	0.046858	0.046481	0	0.000942	0.004156	0.003594	0.001122	0.001132	0.002117	0.003827
F_5	0.047644	0.001047	0.001189	0.007139	0.002562	0.03135	0.002803	0.003702	0.002443	0.016425	0.016886	0.038245	0.019816	0	0.001111	0.002616	0.02071	0.001898	0.001932	0.015889	0.031935
F_6	0.0446	0.000126	0.000105	0.048904	0.002521	0.001055	0.0167	0.001466	0.000933	0.000848	0.015569	0.051689	0.005452	0	0.000443	0.002543	0.046543	0.00081	0.0008	0.000958	0.002875
F_7	0.004562	0.002781	0.001595	0.038796	0.001834	0.046614	0.004329	0.034532	0.032173	0.031345	0.03203	0.029735	0.011833	0	0.015048	0.002342	0.02661	0.031859	0.032771	0.000812	0.046299
F_8	0.001651	0.000268	0.000176	0.00549	0.002944	0.002419	0.031636	0.003535	0.003084	0.002583	0.002618	0.034202	0.032526	0	0.00153	0.017702	0.033293	0.002387	0.002218	0.001503	0.004482
F_9	0.001394	0.044319	0.00014	0.019698	0.003095	0.001534	0.016946	0.002403	0.002229	0.001728	0.001751	0.03652	0.033631	0	0.000905	0.00313	0.03377	0.001286	0.030717	0.001572	0.003514
F_{10}	0.001995	0.000276	0.000192	0.005761	0.00436	0.001974	0.019152	0.047434	0.003069	0.002347	0.002376	0.050199	0.048638	0	0.001244	0.005058	0.034938	0.001713	0.001728	0.002233	0.004779
F_{11}	0.002594	0.000718	0.000604	0.019571	0.003675	0.002525	0.018306	0.033305	0.003633	0.002696	0.002733	0.034893	0.04841	0	0.001191	0.004165	0.005322	0.00227	0.002316	0.001991	0.018946

F_{21}	F_{20}	F_{19}	F_{18}	F_{17}	F_{16}	F_{15}	F_{14}	F_{13}	F_{12}
0.047872	0.001506	0.000839	0.001922	0.000855	0.018488	0.001934	0.001421	0.035892	0.00559
0.031599	0.000191	0.00012	0.000231	0.000121	0.002454	0.000233	0.00018	0.003695	0.001284
0.029589	0.015498	9.84E-05	0.000167	9.87E-05	0.001468	0.014874	0.000136	0.002238	0.001333
0.056761	0.050406	0.018683	0.035145	0.046164	0.040604	0.035607	0.049052	0.057914	0.023478
0.004228	0.003928	0.00292	0.004368	0.002912	0.00401	0.004409	0.003735	0.047163	0.046177
0.045447	0.000989	0.000594	0.001225	0.000602	0.017282	0.001233	0.000935	0.020863	0.005516
0.006541	0.002767	0.002028	0.003102	0.002025	0.00584	0.003131	0.00263	0.035053	0.031287
0.04898	0.00213	0.001154	0.002747	0.001179	0.050279	0.002764	0.002008	0.052845	0.006497
0.046591	0.001966	0.001053	0.002547	0.001076	0.033139	0.002562	0.001853	0.04959	0.005441
0.031236	0.001434	0.000793	0.001836	0.000809	0.032059	0.001847	0.001353	0.034567	0.005067
0.031904	0.001449	0.000802	0.001854	0.000818	0.032313	0.001865	0.001367	0.034874	0.005148
0.051912	0.052499	0.048122	0.050328	0.047408	0.047186	0.051015	0.050258	0.051574	0.010543
0.043916	0.036539	0.018061	0.048669	0.018607	0.043703	0.048933	0.034391	0.017444	0.036135
0	0	0	0	0	0	0	0	0	0
0.000981	0.044896	0.000438	0.00099	0.000446	0.03037	0.000996	0.000735	0.018272	0.003085
0.004948	0.003959	0.002937	0.004408	0.00293	0.004749	0.00445	0.003764	0.04794	0.046272
0.057339	0.034728	0.046554	0.047925	0.002434	0.042921	0.04796	0.047319	0.044832	0.036642
0.045372	0.000949	0.000564	0.00118	0.000572	0.046629	0.001188	0.000897	0.02037	0.005059
0.04667	0.000949	0.000552	0.00119	0.000561	0.032828	0.001198	0.000896	0.021123	0.004538
0.002117	0.001904	0.001282	0.002236	0.001287	0.002038	0.002254	0.001806	0.031377	0.016603
0.004492	0.003531	0.002486	0.00405	0.002488	0.033718	0.004085	0.003352	0.051261	0.035491

Table 9: The matrix $\left[t_{ij}^{M}\right]_{21\times21}$

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}	F_{21}
F_1	0.001837	0.000399	0.000349	0.034349	0.005167	0.001539	0.004102	0.002359	0.002028	0.001719	0.002795	0.063983	0.021244	0	0.001308	0.005202	0.005345	0.00148	0.001493	0.003125	0.004966
F_2	0.002401	0.000444	0.000367	0.005351	0.005024	0.001899	0.004057	0.003145	0.002758	0.002262	0.003149	0.048361	0.033744	0	0.001675	0.00507	0.005389	0.00184	0.001887	0.003253	0.005043
F_3	0.002798	0.00054	0.000454	0.050668	0.006348	0.002245	0.0051	0.003647	0.003183	0.002631	0.003813	0.066432	0.037613	0	0.001962	0.006402	0.006736	0.002171	0.002218	0.004028	0.00629
F_4	0.004397	0.000766	0.000617	0.009108	0.008115	0.003405	0.006611	0.005798	0.005117	0.004151	0.005449	0.066443	0.065532	0	0.003045	0.0082	0.008867	0.003311	0.003416	0.005436	0.008327
F_5	0.068442	0.003905	0.004113	0.039916	0.010077	0.050337	0.01114	0.026479	0.022182	0.035442	0.039259	0.074746	0.053136	0	0.020184	0.010466	0.051941	0.020773	0.021598	0.036805	0.055234
F_6	0.06478	0.002069	0.001891	0.077696	0.022544	0.00636	0.036613	0.00892	0.006505	0.005947	0.037075	0.082591	0.034462	0	0.004998	0.022676	0.071992	0.005825	0.005779	0.020272	0.026024
F_7	0.026166	0.021167	0.004402	0.073611	0.011134	0.066155	0.014452	0.058934	0.052509	0.050907	0.056266	0.069699	0.048392	0	0.033519	0.012001	0.060511	0.051262	0.053402	0.0087	0.071631
F_8	0.008044	0.002557	0.002057	0.033865	0.022956	0.008592	0.051641	0.011784	0.009489	0.008526	0.024865	0.064069	0.06037	0	0.006941	0.037835	0.059603	0.00827	0.008132	0.020859	0.028099
F_9	0.00752	0.06108	0.002009	0.049049	0.02363	0.00746	0.037807	0.025125	0.008445	0.00745	0.024001	0.069572	0.064016	0	0.006057	0.023999	0.061791	0.006915	0.051052	0.021337	0.027285
F_{10}	0.00864	0.002499	0.002203	0.035914	0.025965	0.008426	0.041168	0.070775	0.00976	0.008549	0.026021	0.082125	0.078397	0	0.006892	0.027006	0.063285	0.007851	0.007885	0.02316	0.029898
F_{11}	0.009178	0.00307	0.002742	0.04821	0.024452	0.008904	0.03929	0.055879	0.010227	0.008832	0.011159	0.065476	0.076462	0	0.006811	0.025274	0.032837	0.00835	0.008429	0.022121	0.042864

F_{21}	F_{20}	F_{19}	F_{18}	F_{17}	F_{16}	F_{15}	F_{14}	F_{13}	F_{12}
0.06892	0.004253	0.002902	0.004759	0.002863	0.040242	0.004842	0.003928	0.060956	0.013793
0.049041	0.000771	0.000561	0.000832	0.000551	0.00607	0.000848	0.000713	0.008827	0.004188
0.045779	0.031774	0.000472	0.000671	0.000463	0.004412	0.030096	0.000585	0.006471	0.004014
0.094277	0.074837	0.039682	0.057481	0.065508	0.077296	0.058971	0.070841	0.100612	0.05422
0.015083	0.008534	0.00661	0.008854	0.006468	0.014038	0.00904	0.007911	0.072236	0.06572
0.064478	0.003338	0.00233	0.003691	0.002295	0.037379	0.003757	0.003085	0.044571	0.01332
0.018108	0.006911	0.005309	0.007209	0.005198	0.016714	0.007359	0.006405	0.06129	0.051101
0.07314	0.005583	0.003782	0.006273	0.003733	0.075357	0.00638	0.005155	0.081816	0.016748
0.066458	0.004907	0.0033	0.005535	0.003259	0.05404	0.005629	0.00453	0.073435	0.013561
0.050498	0.004008	0.002728	0.004492	0.002692	0.052169	0.004569	0.003702	0.05789	0.01267
0.056591	0.00547	0.003962	0.005919	0.003893	0.057237	0.006031	0.005061	0.063807	0.028833
0.095271	0.078237	0.06942	0.07334	0.067409	0.0883	0.075294	0.072845	0.10006	0.029476
0.083351	0.061013	0.038918	0.070693	0.038576	0.081308	0.071799	0.056251	0.047563	0.066485
0	0	0	0	0	0	0	0	0	0
0.01955	0.061782	0.002035	0.003298	0.002006	0.049384	0.003355	0.002733	0.041412	0.010356
0.016159	0.008616	0.006665	0.008946	0.006523	0.015147	0.009134	0.007986	0.073439	0.065966
0.091776	0.056786	0.065833	0.068486	0.006867	0.078221	0.068684	0.067355	0.085745	0.064992
0.064244	0.003239	0.002253	0.003587	0.00222	0.066577	0.003651	0.002993	0.043705	0.012576
0.066938	0.003329	0.002301	0.0037	0.002268	0.054033	0.003765	0.003076	0.045865	0.012204
0.011499	0.005587	0.00419	0.005917	0.004108	0.010659	0.006036	0.005174	0.056012	0.036397
0.016958	0.008627	0.006545	0.009071	0.006413	0.05997	0.009256	0.007992	0.081734	0.059821

Table 10: The matrix $\left[t_{ij}^{U}\right]_{21\times21}$

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21
F1	0.040953	0.034394	0.034306	0.091337	0.041471	0.039374	0.045202	0.044317	0.039945	0.040555	0.045221	0.113746	0.079694	0.029857	0.038512	0.042123	0.061142	0.038773	0.040536	0.041018	0.047818
F2	0.041518	0.034332	0.034238	0.062642	0.041969	0.039739	0.045749	0.044934	0.040503	0.041121	0.045816	0.113281	0.093258	0.029738	0.038868	0.04263	0.061847	0.039132	0.040919	0.041538	0.048394
F3	0.043431	0.03589	0.035791	0.10964	0.043899	0.041562	0.047854	0.047005	0.04237	0.043015	0.047926	0.118408	0.098114	0.031084	0.040651	0.044591	0.06469	0.040927	0.042796	0.043449	0.050619
F4	0.043359	0.035309	0.035205	0.065279	0.043754	0.041321	0.047699	0.046932	0.042306	0.042949	0.047818	0.116234	0.11006	0.030516	0.040414	0.044444	0.064447	0.040687	0.042554	0.043332	0.050453
F5	0.107515	0.051632	0.052105	0.117327	0.061853	0.103043	0.069733	0.084186	0.074717	0.090332	0.099391	0.160654	0.134436	0.042192	0.072304	0.063091	0.129015	0.07274	0.076036	0.090721	0.116021
F6	0.099105	0.045275	0.045118	0.132417	0.068457	0.053669	0.088707	0.061479	0.054235	0.055242	0.090872	0.144548	0.106018	0.038057	0.05204	0.069361	0.127422	0.052676	0.055069	0.068345	0.079787
F7	0.083072	0.072167	0.056146	0.15686	0.067503	0.108024	0.077639	0.120812	0.109035	0.110028	0.120576	0.161388	0.134501	0.046089	0.090557	0.069279	0.141481	0.107057	0.111867	0.067115	0.122853
F8	0.057467	0.045944	0.045529	0.105335	0.069941	0.056088	0.104934	0.0642	0.05728	0.058309	0.07944	0.144979	0.13537	0.03823	0.054399	0.085591	0.131013	0.055289	0.057816	0.069866	0.0826
F9	0.060028	0.092449	0.048149	0.124926	0.073393	0.058133	0.094298	0.081022	0.059175	0.060254	0.081884	0.154101	0.143038	0.040571	0.056409	0.074585	0.137005	0.057071	0.103799	0.073286	0.085286
F10	0.057276	0.046019	0.045834	0.105236	0.070962	0.055534	0.092491	0.107514	0.056526	0.05757	0.079319	0.146279	0.136839	0.038523	0.053854	0.072543	0.132297	0.054514	0.057007	0.070898	0.08254
F11	0.0575	0.04632	0.046114	0.118376	0.070362	0.055736	0.091673	0.107085	0.056726	0.057761	0.064793	0.145123	0.136096	0.038218	0.053644	0.071937	0.102801	0.054725	0.057227	0.070297	0.096343

F_{21}	F_{20}	F_{19}	F_{18}	F_{17}	F_{16}	F_{15}	F_{14}	F_{13}	F_{12}
0.116247	0.050604	0.04471	0.047188	0.043431	0.102287	0.048465	0.047188	0.125163	0.064106
0.103268	0.041249	0.036954	0.038451	0.03589	0.060599	0.039506	0.038451	0.066439	0.050298
0.101566	0.071837	0.036852	0.038337	0.035791	0.059696	0.068801	0.038337	0.06576	0.050282
0.165905	0.125647	0.098811	0.117114	0.10964	0.165873	0.120338	0.117114	0.179318	0.127972
0.073632	0.05107	0.045193	0.047621	0.043899	0.072914	0.048912	0.047621	0.121379	0.101334
0.111286	0.048238	0.042788	0.044977	0.041562	0.097893	0.0462	0.044977	0.107518	0.062395
0.084114	0.055674	0.049263	0.051915	0.047854	0.083295	0.053322	0.051915	0.132588	0.107463
0.124952	0.054774	0.048389	0.051077	0.047005	0.126395	0.052459	0.051077	0.135856	0.070591
0.112755	0.049374	0.043617	0.046041	0.04237	0.114079	0.047288	0.046041	0.122564	0.063039
0.113838	0.050125	0.044282	0.046742	0.043015	0.115152	0.048007	0.046742	0.124349	0.064529
0.125033	0.055809	0.049337	0.052042	0.047926	0.125984	0.053451	0.052042	0.136093	0.085639
0.187129	0.135806	0.121923	0.126585	0.118408	0.185191	0.130068	0.126585	0.200806	0.112555
0.171709	0.127518	0.100824	0.119244	0.098114	0.171703	0.12213	0.119244	0.142503	0.144038
0.049156	0.035654	0.032007	0.033233	0.031084	0.048646	0.034148	0.033233	0.052904	0.040805
0.080282	0.091297	0.04185	0.04399	0.040651	0.109724	0.045186	0.04399	0.105076	0.059799
0.075469	0.051876	0.045904	0.048372	0.044591	0.074773	0.049684	0.048372	0.123377	0.102372
0.161993	0.121289	0.110714	0.114262	0.06469	0.164201	0.116165	0.114262	0.176812	0.138603
0.11023	0.047499	0.042134	0.044288	0.040927	0.111554	0.045492	0.044288	0.105762	0.06092
0.115205	0.049677	0.044058	0.046319	0.042796	0.116587	0.047578	0.046319	0.111169	0.063702
0.073045	0.050575	0.044729	0.04716	0.043449	0.072335	0.048438	0.04716	0.121996	0.087953
0.085759	0.058889	0.052111	0.054912	0.050619	0.129075	0.056401	0.054912	0.140028	0.116321

Table 11: The matrices $\tilde{R}_i$, $\tilde{C}_j$, $\tilde{R}_i + \tilde{C}_i$, and $\tilde{R}_i - \tilde{C}_i$

	$\tilde{R}_i$			$\tilde{C}_j$			$\tilde{R}_i + \tilde{C}_i$			$\tilde{R}_i - \tilde{C}_i$		
	R_i^L	R_i^M	R_i^U	C_j^L	C_j^M	C_j^U	RC_i^{L+}	RC_i^{M+}	RC_i^{U+}	RC_i^{L-}	RC_i^{M-}	RC_i^{U-}
1	0.075388	0.164786	1.030294	0.224384	0.411663	1.380614	0.299771	0.576448	2.410908	-1.30523	-0.24688	0.80591
2	0.063842	0.137121	1.022167	0.090132	0.170899	1.050836	0.153974	0.30802	2.073002	-0.98699	-0.03378	0.932035
3	0.116736	0.215279	1.113714	0.069889	0.145943	1.045792	0.186625	0.361222	2.159506	-0.92906	0.069337	1.043825
4	0.132797	0.226111	1.07507	0.611503	1.15146	2.517105	0.7443	1.377571	3.592176	-2.38431	-0.92535	0.463567
5	0.267342	0.656175	1.869041	0.155959	0.379906	1.307139	0.423301	1.036081	3.17618	-1.0398	0.276269	1.713082
6	0.244942	0.545019	1.587897	0.184632	0.343564	1.300057	0.429574	0.888582	2.887954	-1.05511	0.201455	1.403265
7	0.427899	0.844821	2.13405	0.212045	0.437584	1.523381	0.639944	1.282404	3.657432	-1.09548	0.407237	1.922005
8	0.186247	0.478555	1.599618	0.302014	0.550811	1.572058	0.488261	1.029366	3.171676	-1.38581	-0.07226	1.297604
9	0.240284	0.585602	1.758861	0.198014	0.366857	1.319985	0.438298	0.952459	3.078846	-1.0797	0.218744	1.560847
10	0.239465	0.566419	1.619571	0.172412	0.331836	1.353914	0.411877	0.898254	2.973485	-1.11445	0.234583	1.447159
11	0.209863	0.510567	1.598856	0.189833	0.470656	1.586412	0.399697	0.981222	3.185268	-1.37655	0.039911	1.409023
12	0.331186	0.636441	1.774715	0.905657	1.50315	2.963798	1.236843	2.139591	4.738513	-2.63261	-0.86671	0.869058
13	0.678886	1.207447	2.597459	0.629412	1.189325	2.624451	1.308298	2.396772	5.221909	-1.94556	0.018123	1.968047
14	0.208087	0.33832	1.25987	0	0	0.793945	0.208087	0.33832	2.053815	-0.58586	0.33832	1.25987
15	0.23254	0.388495	1.322038	0.124566	0.289303	1.253497	0.357106	0.677798	2.575535	-1.02096	0.099192	1.197471
16	0.52208	0.938555	2.307956	0.175106	0.402712	1.344963	0.697186	1.341267	3.65292	-0.82288	0.535843	2.13285
17	0.133395	0.23331	1.113714	0.619224	1.083042	2.43615	0.752618	1.316352	3.549864	-2.30276	-0.84973	0.49449
18	0.216118	0.352752	1.25987	0.167371	0.323093	1.266685	0.383488	0.675845	2.526554	-1.05057	0.029659	1.092499
19	0.15008	0.269796	1.17645	0.185326	0.362768	1.369037	0.335405	0.632564	2.545487	-1.21896	-0.09297	0.991125
20	0.262219	0.437603	1.424481	0.092948	0.314674	1.316705	0.355166	0.752277	2.741185	-1.05449	0.12293	1.331533
21	0.638496	1.068118	2.342575	0.267465	0.572049	1.66174	0.905961	1.640167	4.004314	-1.02324	0.496069	2.075109

Table 12: The defuzzied value of the fuzzy number $\tilde{R}_i + \tilde{C}_i$

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}
$R_i + C_i$	0.883802	0.589372	0.652791	1.731597	1.384738	1.2246	1.667175	1.385883	1.308611	1.246757	1.345739
Ranking	18	21	19	4	9	13	7	8	11	12	10
	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}	F_{21}	
$R_i + C_i$	2.474984	2.707613	0.612658	0.999478	1.712684	1.684445	0.990018	0.957035	1.088857	1.997061	
Ranking	2	1	20	15	5	6	16	17	14	3	

Table 13: The defuzzied value of the fuzzy number $\tilde{R}_i - \tilde{C}_i$

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}
$R_i - C_i$	-0.24812	-0.04169	0.04865	-0.87912	0.254141	0.160007	0.347983	-0.07622	0.190245	0.174281	0.007392
Type	effect	effect	cause	effect	cause	cause	cause	effect	cause	cause	cause
	F_{12}	F_{13}	F_{14}	F_{15}	F_{16}	F_{17}	F_{18}	F_{19}	F_{20}	F_{21}	
$R_i - C_i$	-0.80127	-0.01917	0.31117	0.074131	0.504151	-0.81813	0.010417	-0.11031	0.103777	0.433741	
Type	effect	effect	cause	cause	cause	effect	cause	effect	cause	cause	