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Content

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Editorial Introduction

Special Issue on "Infrastructure and Transportation Planning"

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Transportation and infrastructure are the most crucial components which affect the development and renewal of cities and regions. The results of infrastructure and transportation planning not only take effect on the accessibility of an urban area, but also, it determines the livability of the whole city (Krizek & Levinson, 2005). Recently, new technologies, concepts and practical means have largely emerged in infrastructure and transportation planning, such as: "Big Data," "Large scale model" and "old-community planning (Cunliang Guihua in Chinese)". These concepts and tools almost reversed the traditional knowledge system and operating mode of urban planning, which has prompted us to carry out the necessary research and work to adapt to these changes (Vlahogianni, Park, & van Lint, 2015). On the other hand, we should still attach importance to the traditional knowledge and practical means by applying them to the new problems arising in the urban planning process today. Consequently, in this special issue, we study new concepts such as the "Big data" in the life-circle community determination, policy instruments on the new energy vehicle industry, and others. Moreover, we also pay attention to the change of urban planning law and survey technology on urban transportation hubs.

There are six papers in this issue. Using the space-time path technique, the first paper (Tsai, Chen, & Ning, 2016) studies elderly people's social support and walking space in Xin-Yi district, Taiwan. As the world's population goes up, aging problems are becoming important issues of concern. However, relatively little research has been carried out on transportation planning for aged people. Wang and Tong (2009) proposed design principles for the pedestrian space of the elderly, which included: (a) safety and accessibility, (b) comfortable and walkable space, and (c) communication and participation. But the walkability indicator was rarely formulated based on the space-time condition. This paper investigates 22 seniors in Xin-Yi district, China by recording of Global Positioning Systems, activity items, space equipment and the walking environment of elders to propose the requirements of walking spaces and the suggestions for improvement in Xin-Yi district.

The second paper (Xiao, Xu, & Liu, 2016) studies how to determine and split the life-circle community unit by using the positioning data of taxi trips. The taxi trip data have largely been used in assisting urban structure

recognition (Liu et al., 2015). The life-circle identification is important for making a reasonable land use plan. Due to date, very little research has been imposed on life-circle determination using big traffic data. In this paper, the taxi trip data of Xiamen City are used to detect the community within the extent of citizens' spatial scale mobility – that is, the life-circle of the citizens. Moreover, the detected life-circle is compared to the urban planning community unit to give the necessary adjustment suggestions for land-use planning of the city.

The following paper (Lin, Dai, & Song, 2016) pays close attention to the travel behavior within comprehensive passenger transportation hubs. It is well known that there will be more and more mega transportation infrastructure emerging in our cities due to the rocketing increase of transportation demand. For instance, with the development of a high speed rail system across China in this century, almost every large city now owns at least one comprehensive passenger transportation hub. In this circumstance, how to investigate the mobility pattern of passengers has become an emerging problem. For determining travel behavior in comprehensive passenger transportation hubs, Román and Martín (2014) employed a discrete choice experiment to better understand the passengers' preferences and found a range of willingness-to-pay values for service quality attributes, such as in-vehicle travel time and connecting time between all transportation modes. From the view of passenger behavior, the related paper in this issue presents a detailed review on how to set up the directional signs for multimodal passengers moving through comprehensive transport hubs, in addition, paying attention to evacuation behavior.

As we know, efficiency assessment for transportation infrastructure is necessary for advancing the decision-making process for infrastructure planning. At the same time, the topic of transportation network efficiency has been a hot research topic since 60 years ago (Transportation Research Board, 2010). The fourth paper in this issue (Li, Z., Zhao, & Yuan, 2016) focuses on an efficiency evaluation of the Beijing-Tianjing-Heibei region. The conclusion is that the highway transportation efficiency of the Beijing-Tianjin-Hebei region is less than that of the Yangtze River Delta and Pearl River Delta urban agglomeration.

Differing to the infrastructure efficiency evaluation, which is always a posteriori, the evaluation of policy or of the Government Procurement Act would be carried out in advance before the construction of an infrastructure. As a result, we present two papers relating to the evaluation of the transportation development policy and Government Procurement Act. The first mentioned paper (Li, D. et al., 2016) evaluates the efficiency of policies on the new energy vehicle industry. The other paper (Huang, 2016) compares the 1998 Government Procurement Act and the 2000 Act for Promotion of Private Participation in Infrastructure Projects.

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Elderly People's Social Support and Walking Space by Space-time Path：

A Case Study of Taipei Xinyi District

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Key words: Elderly, Social Support, Walking Environment, Global Positioning System

Abstract: Due to the trend of global aging, issues of the elderly should be paid attention to. In January 2014, the elderly accounted for 11.57% of the population in Taiwan. By around 2017 Taiwan will become an Aged society. In order to provide seniors with a healthy and better life, the living environment and space arrangements will be important factors in the urban city. This study statistically assesses the walking space and the living path of elders by out-door activity type, walking range time and walking environment to understand the activity conditions and types of elders in Xin-Yu district, referencing the World Health Organisation's recommendations on "Global Age-friendly Cities: Outdoor Spaces and Buildings". This study investigates 22 seniors in the Xin-Yi district using the Global Positioning System, observations and deep interviews to explore the influencing factors, such as activity type, activity item, space equipment and walking environment of elders, to propose the requirements of walking spaces and suggestions for improvement in Xin-Yi district. The result found that the condition of elders' activity and societal support demanded the utilisation of activity environments and walking spaces for social-type elders, including public social spaces, safe road crossings, bus stops and bus information support; for selection-type elders, demand was identified for communication chairs at shopping arcades and diverse sports facilities; and for essential-type elders, demands were on participatory open space and cooperative group facilities. Through the setting and improving of the urban resources above, social support for elders can be improved through the provision of friendly and healthy urban city activity spaces.

1. INTRODUCTION

As the world's population increases, problems related to the elderly are being increasingly noticed. According to the Directorate-General of Budget, Accounting and Statistics in Taiwan the population in Xin-Yi district is 228,125, of which 30,684 people are more than 65 years old and the proportion of the aged population is 13.45%, close to the United Nations standard of an aging society at 14%. The district of Xin-Yi is a very important part of Taipei. There is much construction and its city planning is representative in Taiwan, so it should examine the environmental lifestyle needs of the elderly. This study discusses the elderly people's social support and walking space in Xin-Yin district by the type of the outdoor activity, walking time and pedestrian

path environments, as well as other factors, to understand the activity condition of the elderly in Xin-Yin district, and to quantify the maximum number of the activity spaces within the walking space of a neighbourhood. Through the establishment of these, social support improvements for the elderly can be identified, including more social support and activities.

2. CONTENT AND METHOD

2.1 Literature Review

2.1.1 Elderly pedestrian space

As people age, their physical capacity declines and the range of their activities becomes reduced, therefore, the design of pedestrian spaces becomes more important for seniors, also affecting their quality of life and environmental support. The design principles for elderly pedestrian spaces include: 1. Safety and accessibility, 2. Comfortable and workable space, 3. Communication of information, and 4. Participation (Wang & Tong, 2009; Xin, 2007). However, regular participation in physical activity can significantly improve an individual's physical, cognitive and emotional health at an older age (Mitra, Siva, & Kehler, 2015; Kerr, Rosenberg, & Frank, 2012). Borst et al. (2008) investigate 546 seniors in Portland, U.S.A, to discuss the pedestrian spaces that include seniors' activity. The result shows the number of shops within a senior's walking distance can affect the time that seniors spend walking.

Nowadays, the ecological theory of ageing emphasizes the importance of an interaction between a person and the environment for healthy ageing. Old age is identified as a critical stage in life when physical (i.e., the human built) environment can profoundly restrict an individual's health and wellbeing (in this context, active ageing including walking). The environmental support factors affecting seniors' walking habits include: 1. Traffic conditions and street design, 2. Sidewalk quality, 3. Benches, trees and places to rest, 4. Personal safety, and 5. Proximity to parks and natural landscapes (Mitra, Siva, & Kehler, 2015).In addition, there is research using an "age-friendly city check list" to investigate 220 seniors in Taipei city, and the data shows most of the senior citizens often go to public facilities, including: 1. Parks (18.3%), 2. Markets (13%), 3. Community centres (10.2%), 4. Temples/churches (7.3%), and 5.Green land (6.6%). According to this finding, parks are the most important activity space for seniors (Tsai, 2014). The design principles of pedestrian walkways and the walking advantages for seniors, according to a literature review, are shown as below (Table 1).

Table 1. Design principles of pedestrian way and walking advantages for seniors

Author/Year	**Design Principles of Pedestrian Way**	**Senior Walking Advantages**
Wang & Tong 2009	Safety and accessibility. 2. Comfortable and workability space. 3. Communicative. 4. Participation.	Improve the life and environmental qualities.
Mitra , Siva, Kehler 2015	1. Traffic conditions and street design. 2. Sidewalk quality. 3. Benches, trees and places to rest 4. Personal safety 5. Proximity to parks and natural landscape 6. Proximity to parks and natural landscape.	Cognitive and emotional maintenance healthy, Improve the Body functions

Corey 2008	Increase the number of shops the range of 400m, can increase walking distance with senior as well.	Improve the Body functions.
Tsai 2014	Senior often go to public facilities are 1.parks (18.3%). 2. Market (13%). 3. Community centre (10.2%). 4. Temples/ church. (7.3) 5.green land (6.6%)	Park is the most important activity space for seniors.

In the future, design principles supporting elderly pedestrians should reduce environmentally dangerous hazards and enhance safety for seniors. Secondly, they should provide comfort facilities for seniors, such as benches, parks and recreational areas. Lastly, basic livelihood facilities, such as shops, community centres, etc. should be provided within the range of 400m. These design principles have the potential to improve bodily function and social support for seniors.

2.1.2 Time and space path

The 'Lifestyle model' means describing the physical environment using measures of personal activity, time and space to explain people's real life form (Tzeng & Wang, 2006). All of the space that people may be in direct contact with on a daily basis is referred to as the 'activity space'. Space is an important manifestation of daily life, and daily activity spaces can be divided into three parts: 1. Moving from home to the surrounding area, 2. Round-trips between general activity locations, and 3. Moving around within activity spaces. Using these three activities as the basis, activity space can be conceptualized as a hierarchy of movement. The concept of space-time path expression is to express activity as behaviour in space and time; paths can be used to express a whole individual behaviour, including mobility paths, dwelling time and activities (Golledge & Stimson, 1997).

2.1.3 Elderly Social Support

Tsai (2015) and Godbey (1999) research the theory of aging and the relationship of social support with the elderly, and consider that with ageing social interaction will be reduced. However, participation in leisure activities can help to improve physiological function and slow down the aging process for seniors; through social support, the quality of life can be improved (Hirao et al., 2012). There are primarily five influential forms of social support for the health status of the elderly: instrumental support, emotional support, information support, interactive community support and close, family support. Instrumental support directly affects the health of the elderly, increased social support and social networks can reduce the risk of depression, as well as raising quality of life, and enhance the independence of daily living.

(1) Emotional support: The expression of positivity and consideration.

(2) Information support: Messages of advice, guidance or evaluation support.

(3) Instrumental support: Providing material assistance or psychological support.

(4) Social support interaction: Familiar social integration in or around the home.

(5) Close support: The expression of love and affection.

Previous research has proved instrumental support and intimacy have a significant impact on other social support factors, including social support interactions, such as with mental and physical health, the physical environment, increased energy and increased social behaviour. Therefore, through modelling the daily activity paths, activities and behaviours of the elderly and their daily events can be observed.

2.2 Research Methods

This research uses the GPS location tracking function and in-depth in-person interviews to study 22 elderly people in Xinyi District, Taipei. Following this, the GPS records are used to statistically assess the places, walking and activity behaviour of the elderly. Necessary social support for the elderly is thereafter identified based on their activity.

3. RESEARCH ANALYSIS

In this research, the activity paths of 22 elderly people are identified. The observations include: Daily life paths, walking time and distance, outings, etc., and the total distance and time, and from the research to the analysis, the relationships between length of the walking, activity type and workplace behaviour are identified. Then, possible ideas for improvement in the future are recommended.

3.1 Activity type for the elderly

There are three types of outdoor activities: social type, selection (or optional) type and necessary type (as Table 3.1).

Social type: Defined as the range of activities and activity participation being both within and outside Xinyi District.

Selection type: The range of activities is within Xinyi District, includes daytime activities of more than two types and does not require a long stay at the same location; activity paths are more varied.

Necessary type: These activities require staying for a long time at the same location, where the range of activities is within the nearby village, and activities must be necessary in the daily lives.

As in Table 1, much of the Elderly Activities are of the selection type and there are 11 people active within this type. Second is the social type, with seven people in this type, and last is the necessary type, with four people in this group. Walking time from most to least is: necessary type, social type then selection type. Walking distance from most to least is: social type, selection type then necessary type.

This research, using GPS records, found that the social type of the elderly has the longest walking distance and will take transportation. The selection type of the elderly spends the least time walking, and activities are more changeable. The necessary type of the elderly has the shortest walking distances, but they spend the most time on walking because their activities are necessary to do in their daily lives, so the range is nearby their house, within 500m. Because the distance is short and their attitude is casual, they spend more time walking than the others. The necessary type has the purpose of casual walking for leisure, but those of the social and selection types have the

purpose of walking for transportation. The research data of walking distance and time has been analysed as below (Table 2).

Table 2. Walking distance and time

Types	People	Xinyi District【walking time (minute)/distance (meter)】
Social	7	76/2960 meter
Selection	11	65 /2222 meter
Necessary	4	86 /1274 meter
Total	22	72 /2284 meter

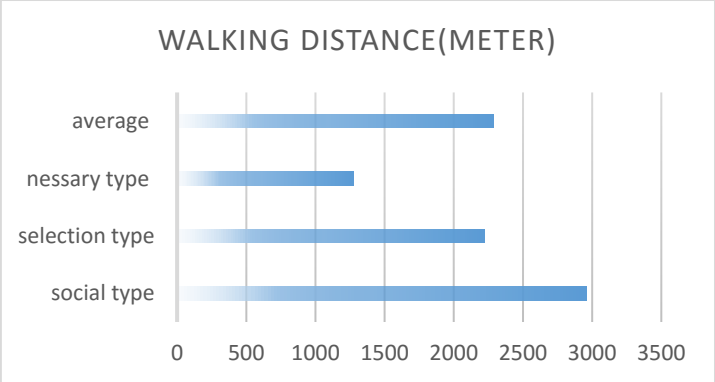

Figure 1. Walking distance with different types of seniors

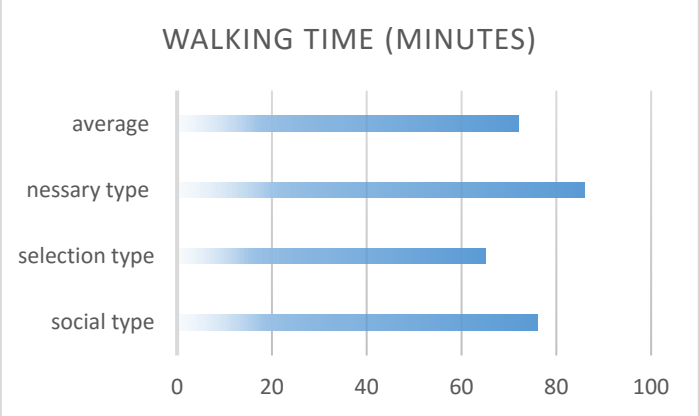

Figure 2. Walking time with different types of seniors

Figure 3. An example of an individual's walking path for a day

Figure 4. An example of an individual's walking path for a day

3.2 Needs for walking and activity spaces for the elderly

The walking purpose for the elderly is divided into two, "transportation" and "leisure". Those of the social type have the purpose of walking as a means of transportation. Those of the selection type have the purpose of walking as a means of both transportation and leisure, and those of the necessary type have the purpose of walking primarily for leisure. The conditions of walking spaces for the purpose of transportation are: street aesthetics, street connection, public facilities and property, livelihood facilities, and comfort of pedestrian space, and safety; The conditions of walking spaces for the purpose of leisure are: street aesthetics, livelihood facilities, comfort of pedestrian space, open space near nature, sports facilities for public, and social support facilities. Distance for the social type of elderly to walk to an activity space is within 12 minutes, or 675 meters, where most of the places constitute a part of the community centre, including mountain areas, sports centres, hospitals and clinics, public agencies, large exhibition games and so on. Demand exists for events and walking paths, including public facilities availability, sociability of open seating areas and the connecting of safe streets. Distance for the selection type of elderly to walk to an activity space is within 10 minutes, or 343 meters. Most of the places visited are squares, parks, shops, churches, mountains and other places, while demand for activities and walking paths includes demand for shop arcade seating areas and sports facilities. Distance for the necessary type of elderly to walk to an activity space is within six minutes, or 145 meters. Most of the places visited are markets, parks, shops and community plazas, while demands for activities and walking paths include demand on activity communication and open space participation.

3.3 Social support for activities of the elderly

The effect of the elderly activity types depends not only on personal factors, the types of activities, venue and facility factors, environmental factors and community factors, but also on social support. Social support is an important consideration for the elderly, during their activities seniors can receive emotional support, information support, instrumental support, and interactive social and intimate support. In addition, this research also incorporated the religious activities of elders. This research therefore not only

discusses the emotional support, information support, instrumental support, interactive support social and intimate support, but also religious support in the form of physiology, psychological perception, social contact, sensory experiences and others.

Social type: Most of the social type elders take the bus to participate in various volunteer services. Although the service types differ, the elderly experience social support during the volunteer activities, including forms of fitness and service. By serving people to promote their positive life in old age, and creating their own social groups, this type of elders can experience emotional support, instrumental support, messaging support and social support from the service. Elders involved in fitness are mostly alone during their activity, and therefore this type of elder does not get the same messaging support and social support from the service.

Selection type: Most of the selection type elders take the bus, motorcycle or bicycle to the activity places. Their activities are motivated by personal interest, which is divided into three categories: personal activities category, sports category and religious category, as described below.

Category of personal activities and sports: These activities come in many kinds, though the interaction between people is less and the time spent is short, these types of elders can get emotional support, instrumental support and information. The sport type of elders, are mostly alone during their activity and the range is short, therefore this type of elders can receive instrumental support only.

Religious type: For this type of elders the activities are related to religious activities and most of the activities are group activities. Therefore, the religious type of elder can receive social support and religious support, which includes emotional support, instrumental support and messaging support.

Necessary type: This type of elder walks to their activity space to meet their basic needs of daily life. Most the activity places are in the nearby community and include community care centres, markets, community squares, neighbourhood parks, and they can get emotional support, instrumental support and messaging support during the activities.

Table 3. Social support for the different types of elders

Range of Activities	Types of Activities	Emotional Support	Instrumental Support	Information Support	Interactive Community Support	Religious Support	Activities place /Transportation
2050m	Social type Service type	+	+	+	+	-	Community care centre, senior centre, park, sports centre /bus, walk
	Social type Sport type	+	+	-	-	-	
700m	Selection type Personal activities	+	+	+	-	-	Shops, cafes shops, activity centre, park, mountains, plaza, church, campus /bus, walk, bicycle
	Selection type Sport type	-	-	+	-	-	

	Selection type Religious type	+	+	+	+	+	
200m	Necessary type	+	+	-	-	-	Markets, parks, community care centres, community plaza /walk

As the Table 3 shows, each different types of senior can get different kind of support. Besides that, they also use different types of public facilities and have different ranges of the activities.

3.4 Pedestrian space, social support and Age-friendly City Checklist

This study combines the walking space facilities and the social support for the social type, selection type and necessary type of elders. Then through the elders' outdoor activities, walking time-path and space facilities, suggests the needs of elders in their spatial environment. The different types of seniors use different spaces and can receive different types of social support from their activities, summarised as below in Table 4.

Following this, analysis of the social support from the elders' outdoor activities is used to identify needs for pedestrian walkways and social support, which are checked against the Age-friendly City Checklist of the World Health Organisation (WHO). Combining the needs in these lists, this research could provide a valuable reference for urban planning in the future.

Table 4. Pedestrian space, social support and age-friendly city checklist

Type	**Pedestrian space**	**Social support**	**Aged-friendly City Checklist**
Social type Service type	1. Safety of street at night 2. The availability of bus stops 3. To create more communicative spaces in the neighbourhood	1. Information support at bus stops 2. Provide more indoor activity spaces	1. Night lighting and sound tips on pedestrian walkways 2. Provide checklist of natural pedestrian walkways 3. Provide more indoor activity space in public spaces
Social type Sport type	1. Activity spaces connecting safe streets 2. Provide seating areas	1. Information support at seating areas 2. Provide more indoor activity spaces	1. Provide checklist of natural pedestrian walkways 2. Provide more indoor activity space in public spaces
Selection type Personal activities	1. Provide seating areas 2. Provides more activity facilities	Provides a gathering place for exchange within five minute walking range	1. Provide seating areas in arcades 2. Provide more shops near to activity spaces
Selection type Sport type	1. Provide seating areas 2. Provide more activity facilities	Provide a gathering place for exchange within five minute walking range	Provide seating areas

Selection type Religious type	Religious space entrance useable by elders	Provide more communications areas near to religious buildings	Increase religious building entrance accessibility projects
Necessary type	Facilities are comfortable, with shelter.	Provide more activities in the neighbourhood parks and facilities	Provide more activity areas in the neighbourhood

According to Table 4, the demands on the pedestrian walkways and social support are organized to form an Age-friendly City Checklist. This found that providing more activity spaces and rest areas could improve social support for elders. The social type of elder needs more indoor activity space and more communication space near pedestrian walkways. Selection type elders need shops, sport facilities and communication spaces. Necessary type elders need communication spaces in neighbourhood parks and plazas.

4. CONCLUSION

This research uses the Age-friendly Cities Index to analyse the walking paths and activity space of 22 elders, and to discuss their social support. The needs to be improved upon and fixed are identified, and a contribution to the planning of pedestrian spaces in Xinyi District is presented. The results are as follows:

There are three types of outdoor activities for the elders in Xinyi District. From most to the least common is selection type, social type and necessary type elders. Social type elders have the longest walking distance and use public transportation. Therefore, to assist social type elders, the community could create more “nodes” such as bus stops or other transportation hubs and communication spaces on pedestrian walkways. Selection type elders spend the shortest time walking because they use other forms of transportation, such as bicycles, vehicles and public transportation well, so to provide more trees and shelter around pedestrian streets and bicycle paths, could enhance the health and safety of outdoor activities.

Necessary type elders have the shortest walking distance, but spend the most time walking. Their activities are limited by the accessibility of neighbourhood parks and markets. Therefore, planning social spaces could improve the social support for this type of elder.

The recommendations for social activity support for elders are as follows:

1) Planning to improve travel: Providing information support at the bus stop and public places for the elders, as well as providing communication spaces in the activity areas.

2) Integration and connection with pedestrian walkways: Recreation, rest and communication spaces and shops should be integrated. Also, small communication points around religious building should be provided.

3) To create more communication activity spaces: Create more communication activity spaces in the neighbourhoods and parks, and the community centre must have enough activities that support group work as well as other facilities that support the participation of elders.

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Detecting Urban Dynamics with Taxi Trip Data for Evaluation and Optimizing of Spatial Planning:

The Example of Xiamen City, China

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Key words: Taxi trip data, Urban dynamics, Spatial planning, Xiamen

Abstract: Commonly, it is very hard to examine underlying urban dynamics due to rapid spatial expansion and land use variations. In this paper, the origin-destination (OD) data extracted from taxi trip data collected in Xiamen, China, covering 30 days was utilized to detect the underlying dynamics of Xiamen City. Specifically, we discretized the study area into 400m*400m grids so that the number of originating points and destination points of the taxi trips could be counted separately within each single grid. Then, heat maps of the taxi mobility were made to achieve a general understanding of urban dynamics. Secondly, we took advantage of the concept of complex networks to analyze the daily taxi trip data. Using a method of community detection, we divided the study area into six main sub-regions called functional self-sufficient zones (FSZs) in which spatial associations are tight and dense. The features of these FSZs helped us to gain a deeper understanding of urban dynamics. Finally, based on this understanding, we further evaluated and optimized the urban spatial planning of Xiamen. Balancing land use allocation was suggested to enhance the multi-centric structure and reduce congestion. This study provides a relevant contribution by exploring the potential of applying taxi trip data to identify urban dynamics revelations and urban planning optimization solutions.

1. INTRODUCTION

Spatial planning is the most traditional and widely used planning paradigm used in urban planning processes, especially in Asian countries. Compared with modern western urban planning, which quantitatively analyzes and solves urban problems through building a vigorous index system (Alexander, 2000; Benevolo & Landry, 1967), spatial planning in China has been relatively more subjective and drawn from much attention to aesthetics. Traditional spatial planning has been trying to manage individual travel behavior by means of mere construction of physical environment. However, such arrangements on future city life seem to fail in achieving the goal of "better cities" that the political and professional elites have expected. This kind of failure has aroused wide discussions in academia. On the other hand, there is still little empirical research evaluating and examining the rationality and effectiveness of proposed urban planning objectives and quantifications

in China. The sharply expanding urban scale, increasing unpredictability and complexity, have made understanding urban dynamics more difficult.

Fortunately, in recent years, the availability of big geospatial data, such as cell phone data, public transportation card records and taxi trajectories, has boosted research on the detection of urban dynamics (Lu & Liu, 2012). Compared with other public transportation, such as bus and metro, which are constrained to prescribed routes, taxis can travel freely to reach different places where other public vehicles cannot get. Moreover, taxi trip data can reflect people's activities through information related to the spatio-temporal connections of origin and destination. Taking advantage of the diversity of routes as well as accurate spatio-temporal information, taxi trip data offers a richer and more detailed glimpse into human mobility patterns (Liang et al., 2012; Wang et al., 2015). Moreover, human mobility studies based on taxi trip data have been applied in many fields, such as traffic management (Yuan, N. J. et al., 2013), urban structure detection (Liu, X. et al., 2015), and land use analysis (Pan et al., 2013; Peng et al., 2012; Yuan, J., Zheng, & Xie, 2012). But a lot of relevant research tends to analyze taxi trip data from the pick-up points and drop-off points in separation. Thus, the spatial interaction of the mobility is omitted. Furthermore, there has been little research applying taxi trip data to evaluate and optimize the urban spatial planning scheme. Most of the existing studies focus on exploring the human behavior and mobility information from taxi trip data.

Among research of individual travel behavior and urban dynamics, the complex network concept has been widely used to detect spatio-temporal connectivity relationships. Due to that, "community" is the most important concept, or structure, in both the individual network and overall urban plan, as it has been evaluated intensively in complex network studies. Newman and Girvan (2004) defined the community as "a sub graph containing nodes which are more densely linked to each other than to the rest of the graph". In the context of urban planning, community is able to demonstrate the underlying dynamics of cities, which are often omitted or surmised subjectively by traditional planning. As community detection can be considered a process for dividing complex networks into several sub networks, among which the internal connections are extraordinarily closed, many researchers have emphatically studied the formation process of communities. Gao et al. (2013), Roth et al. (2011), Liu, Y. et al. (2014), Austwick et al. (2013) and Liu, X. et al. (2015) all focused on this topic, however, all of these researchers failed in evaluating the urban practices with revealed urban dynamics phenomena.

In this paper, the origin-destination (OD) data extracted from the taxi trip data collected in Xiamen, China, covering 30 days was utilized to detect the underlying dynamics of Xiamen City. Specifically, we divide the study area into 400m*400m grids so that the number of originating points and destined points of the taxi trips could be counted separately within every single grid. Then, heat maps of taxi mobility were made to achieve a general understanding of urban dynamics. Secondly, we took advantage of the concept of complex networks to analyze the daily taxi trip data. With the method of community detection from complex network theory, we detect six communities, which are named functional self-sufficient zones (FSZs) in the study area. The features of these FSZs helped us to gain a deeper understanding of urban dynamics. Finally, based on this understanding, we further evaluated and optimized the urban spatial planning of Xiamen.

This paper has been organized as follows, in the following section the methodology for community detection is presented, then, following is the case study section in which the proposed methodology is applied to detect the

community of Xiamen City based on its taxi trip data. Following this, the discussion and conclusion are provided.

2. METHODOLOGY

2.1 Study area

Xiamen City is a coastal city of Fujian province, China, and one of the special economic zones opened to international investment when China started its economic reform in the 1980s. Since the 2000s, Xiamen has developed from an island city to a coastal bay city. Two out of six administrative districts lie on Xiamen Island, which is the central business district (CBD) of Xiamen City. The other four administrative districts are located on mainland areas. The urban configuration of Xiamen City is shown in Figure 1. According to the *Master Plan of Xiamen City (2010-2020)*, there will be two CBDs by 2020.

Regarding the transportation system of Xiamen, currently, there are two railway stations and an airport in Xiamen. In addition, an airport is under construction and will be in operation by 2020 in Xiang'an district. There are also the metro system, which is currently under construction, and three lines which will be put in operation by 2020. Regarding the taxi system, the total number of taxi cars is about 7,500. They account for a large proportion of the travels inside the city.

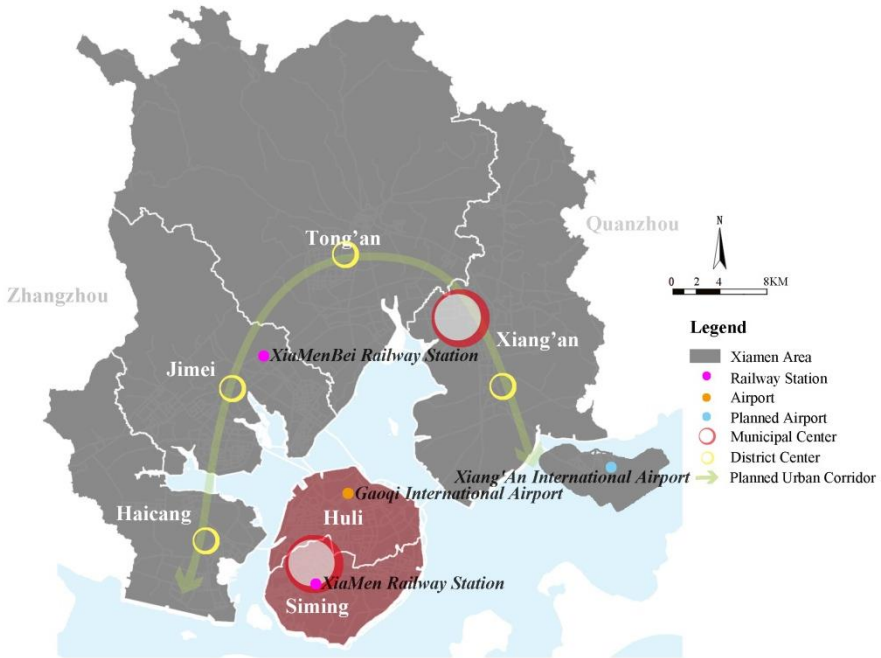

Figure 1. Study area of Xiamen

2.2 Study framework

With the help of analysis methods based on community detection and complex network theory, this research expects to solve the following three problems:

1). How will taxi trip data help us to achieve a general understanding of urban dynamics?

2). How can we take advantage of the complex network built based on the origin-destination (OD) data which were extracted from the taxi trip data to better understand urban dynamics?

3). How can proposed urban land use planning be guided and enhanced based on the underlying urban dynamics revealed by taxi trip data?

It has been shown that taxi trip data could not only reflect a large proportion of individual travel habits, but also, it is used as a data source for research on urban dynamics. Accordingly, the following analytical framework is designed to solve the problems above. As shown in Figure 2, we firstly obtain a general understanding of urban dynamics according to the spatial distribution of taxi trips data. Then we extracted daily taxi trips from taxi trip data. Secondly, we built a network using the daily taxi trips and analyzed this network using a method of community detection to display the underlying principle of the urban dynamic. Furthermore, the evaluation and suggestion for current urban planning schemes were carried out based on the preceding operations.

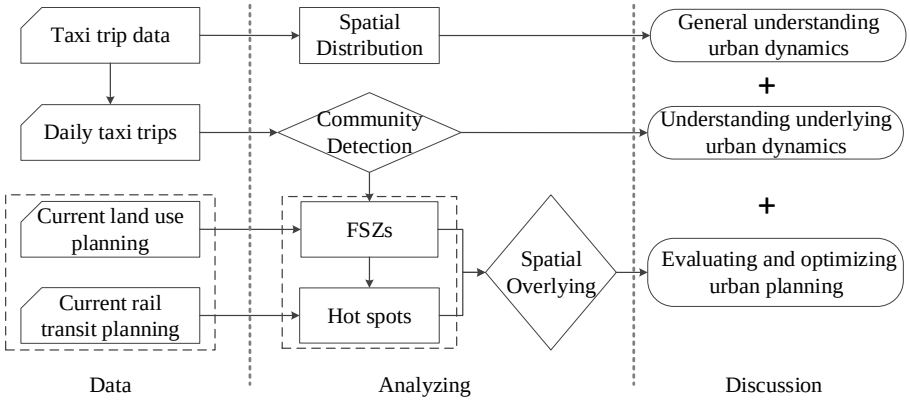

Figure 2. Analytical framework

In Figure 2, the functional self-sufficient zones (FSZs) are detected by the complex network theory; we analyzed the distribution of taxi trips on weekdays and weekends separately, which enabled us to achieve a general understanding of the travel rules. It can be inferred that on weekdays people mostly commute, which means trips are more regular on weekdays and more random on weekends. Trips occurred periodically. In order to eliminate irregular trips, we firstly remove the trips on weekends as well as Fridays when the trips are more or less influenced by the following weekends. Then we remove the haphazard trips occurring from 0:00 to 18:00.

3. ANALYSIS

3.1 Data source and data structure

We use 30 days of taxi trips from March 01 to March 30, 2015. There were nearly three hundred thousand taxi trip records every day, and each taxi trip recorded in the data set was composed of key information such as taxi ID, original point coordinates, destination point coordinates, time interval and trip length. For pre-processing the data set we removed the invalid records such as

those with a trip length less than 500 meters, or those beyond the administrative boundary of Xiamen.

3.2 General understanding of urban dynamics

3.2.1 Data pre-processing and hot spot analysis

The taxi trip data (over 30 days) was used to examine urban dynamics. In order to ensure the accuracy of taxi car movement, we removed records which were deemed invalid. For example, those with a trip length less than 500 meters or beyond the administrative boundary of Xiamen.

The urban dynamics are closely related to daily travel behavior, therefore it is necessary to extract daily trips data from the whole database. Firstly, we extract the daily trips from the whole database using the judgements of a Structure Query Language (SQL) to remove the night trips which occurred between 0:00 to 18:00.

For two types of taxi trip data, the working day data and weekend day data, we divide the study area into 400m*400m grids so that the number of originating points and destination points could be counted respectively within every single grid. Then, we count the amount of ends (including the origin and destination ends) of taxi trips in each grid. Accordingly, we plot the Probability Distribution Function (PDF) of the taxi trip end-points among the total grids in the Log-log scale. The resultant curves have been shown in Figure 3, below. Moreover, we obtain a heat map based on taxi trip end-points for the total grid. As shown in Figure 4, the two heat maps of the taxi trip end-points, in both the weekday and weekend, clearly display the busy degree of overall individuals' mobility in the city. According to Figure 3, it can be see that individual travel behavior is more random on weekends, while it is with more regularity on weekdays; the PDF of the number of taxi trip ends in the weekday has a longer tail than that in the weekend. This situation implies that taxi trip frequency is almost the same for each weekday. On weekdays, taxi trip frequency differs and the amount of taxi trips is relatively more random, which results into a shorter tail, as shown in Figure 3.

Furthermore, we detected the "real" CBD of Xiamen City based on heat map scenes displayed in Figure 4. As shown, we found that the two heat maps are similar; it could be determined that those places with the deepest color would account for the largest proportion of trips on both weekdays and weekends. In other words, these places are the real CBD of this city.

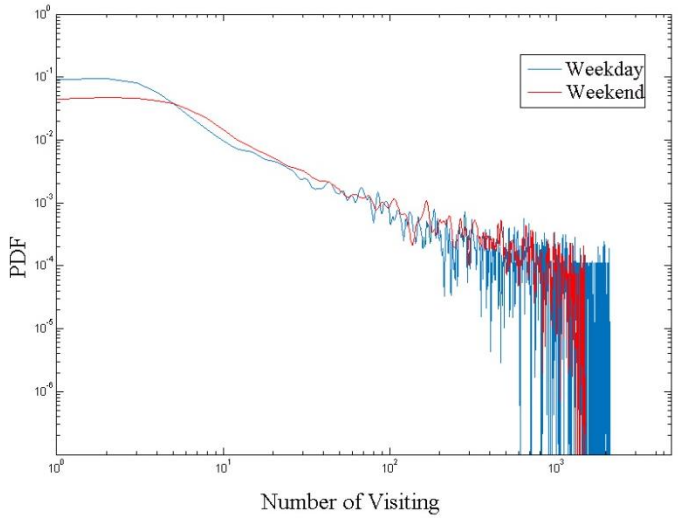

Figure 3. Log-log plot of the taxi trip frequency distribution of different grids on weekdays and weekends

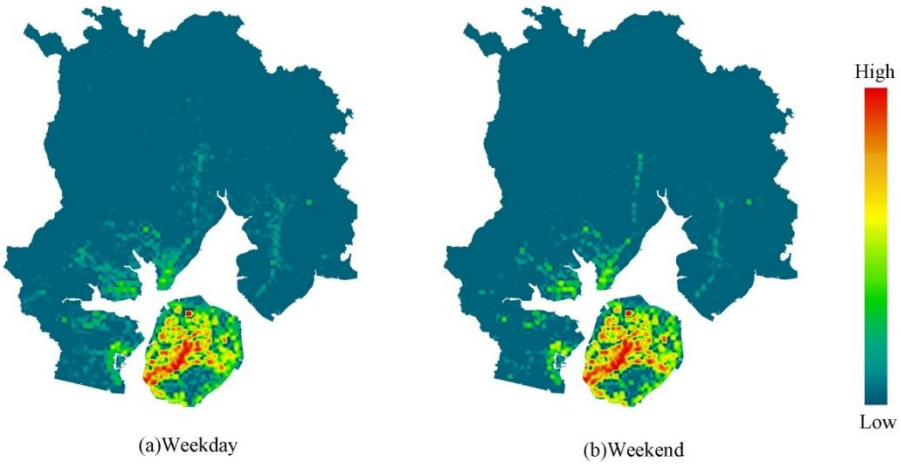

Figure 4. Heat maps of taxi trip dynamics on weekdays and weekends

3.2.2 Trip length distributions

We also study the length of taxi trips for both weekdays and weekends. As shown in Figure 5, trip length distribution (TLD) of taxis follows an exponential distribution. As shown in Figure 5, the TLD consists of two distance ranges: the long length trips, of which the TLD is longer than 8km, and the short length trips, with a TLD smaller than 8km. Among them, the short length trips accounted for 81.1% of all trips, while the total length of the short length trips accounted for 57.6% of the length of all the trips. As we know, the trip purposes have a great influence on the TLD. As illustrated in Figure 6-a, the short distance trips are distributed densely in the CBD area; daily travel by taxi, such as for commuting, shopping and entertainment, tends to head to the bustling regions. Meanwhile, other forms of travel include catching the train or tourism to the outside of Xiamen Island, necessitating long distance travel. It is clear that short length trips on weekdays were able to represent residents' daily travel behavior better than long length trips. The short length trips enabled us to observe the urban dynamics more deeply.

Consequently, we would best detect the urban dynamics using the short length trip data.

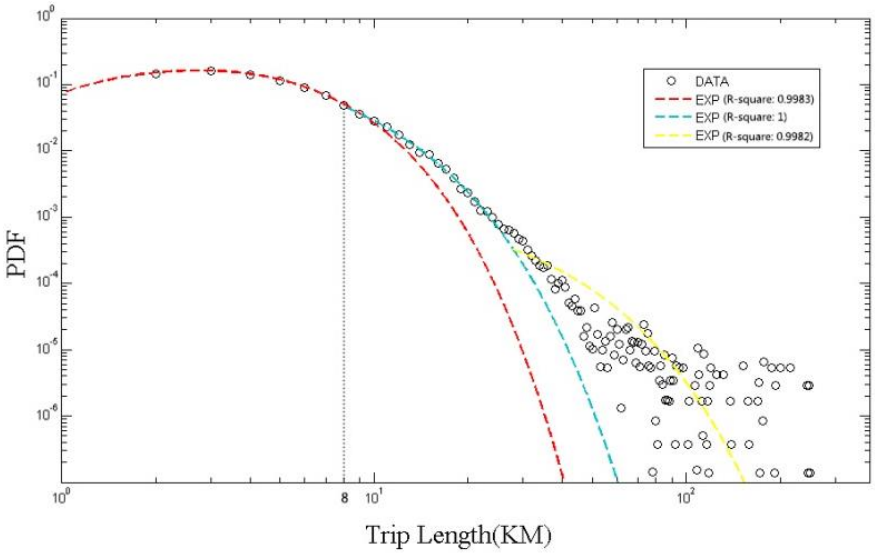

Figure 5. Log-log plot of the distribution of taxi trip length

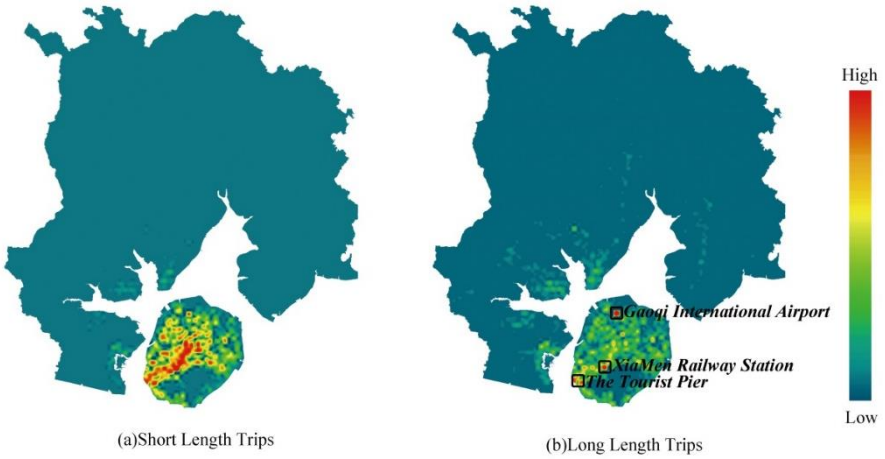

Figure 6. Heat maps of taxi trip dynamics of different length

3.3 Community detection

3.3.1 Network construction and community detection

Complex network theory is traditionally used to analyze the evolution process of a natural phenomenon. In order to identify the urban dynamics process of Xiamen City, we built a directed graph, with which the dynamic nature of mobility in the whole citywide area is examined. Firstly, we divided the study area into different grids. Each grid is 400m*400m and its center is deemed a node of its respective graph. Secondly, we compute the origin-destination (OD) ends of daily taxi trips between any two grids. The OD connections between grids are the links of the graph.

For the community to be identified on a graph, many algorithms have been used in previous works (Malliaros & Vazirgiannis, 2013; Newman, 2013).

Among these algorithms, the Fast Unfolding Algorithm (FUA) is a graph partition method based on the modularity optimization technique, which specifies the community using the direction and weight of the links (Malliaros & Vazirgiannis, 2013). Simultaneously, it divides the detecting of commuting into various hierarchy structures, or intrinsic multi-level characteristic groups. Thus, it can define an appropriate resolution value according to the hierarchy and degree of clustering as needed (Blondel et al., 2008). On the other hand, as most urban scholars pointed out, interaction among the spaces was influenced by land use types, demographic and other geographic factors (McLaughlin, 2012). Moreover, urban scholars are traditionally interested in detecting the regions in which most residents' daily moves were completed t. It implies that the infrastructure and social services within this type of region can meet resident's basic living demands. Therefore, these regions are named functional self-sufficient zones (FSZ) in previous studies. In this paper, our work mainly lies in the detection of FSZs within Xiamen City by using the grid graph weighting of taxi trips.

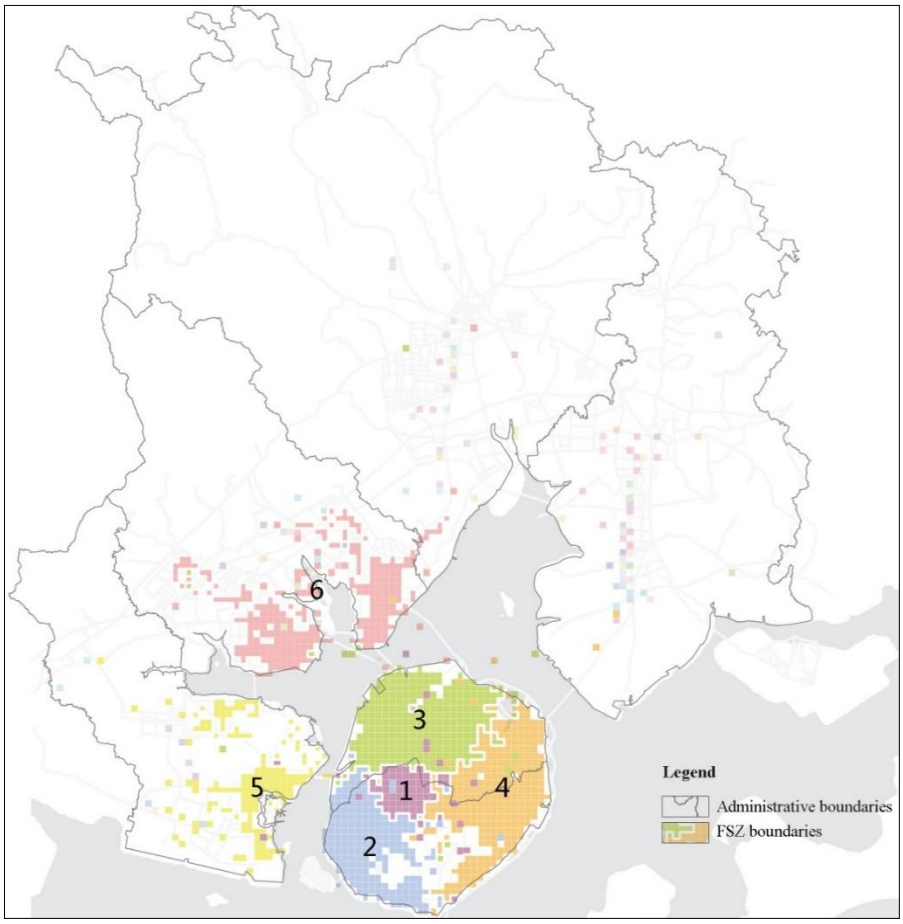

Figure 7. Functional self-sufficient zones (FSZs) detection result based on daily taxi trips

After setting the resolution parameter in the FUA as 0.5, we find that there are six main FSZs citywide, after carrying out the community detection algorithm as Blondel et al. (2008) did. The community detection result is shown in Figure 7, illustrating the number of nodes (a node represents the center of a 400*400m grid) located within the six FSZs, which take up 91.93% of the total area. Four of the six FSZs lie on Xiamen Island, while the other two are on the mainland areas. Compared to the administrative districts of

Xiamen city presented in Figure 1, most of the FSZ boundaries differed from the administrative boundaries; the resulting division presents a polycentric structure in Xiamen City.

3.3.2 Properties of the six FSZs and the hot spots

In order to study the properties of the six FSZs, we propose the corresponding indicators, including the degree, the average degree, the weighted degree, the average weighted degree and the graph density, where, the degree of a node refers to the number of nodes connecting it. Accordingly, the average degree indicates the average number of connections a node is linked to and the weighted degree denotes the amount of taxi trips between one node and another. Similarly, average weighted degree is the mean of weighted degrees of all the nodes. And, the graph density represents the degree of saturation or integration of the network.

According to Table 1, the six FSZs can be divided into three groups. Specifically, the first group is FSZ 1, which covers the least nodes, yet, it owns the highest value of trips, average degree and average weighted degree. On the other hand, group 2 consists of FSZ 2, 3 and 4, whose properties are relatively closed. Finally, FSZ 5 and FSZ 6 belong to group 3, and their attributes are obviously smaller than those of the former two groups. We can conclude that FSZ 1 is the exact core of Xiamen City. Moreover, human travel mobility is mainly concentrated on Xiamen Island, while the mainland areas of Xiamen City are far inferior to Xiamen Island in terms of taxi trip frequency during weekdays.

Table 1. Properties of the six FSZs

FSZs	Nodes	Edges	Trips	Average degree	Average weighted degree	Graph density
1	74	21362	78629	320	1278	0.048
2	198	18374	67535	184	684	0.042
3	274	29297	72206	148	370	0.057
4	279	23833	54867	117	267	0.048
5	149	718	1098	8.3	12.3	0.014
6	259	917	1207	6.6	8.3	0.009

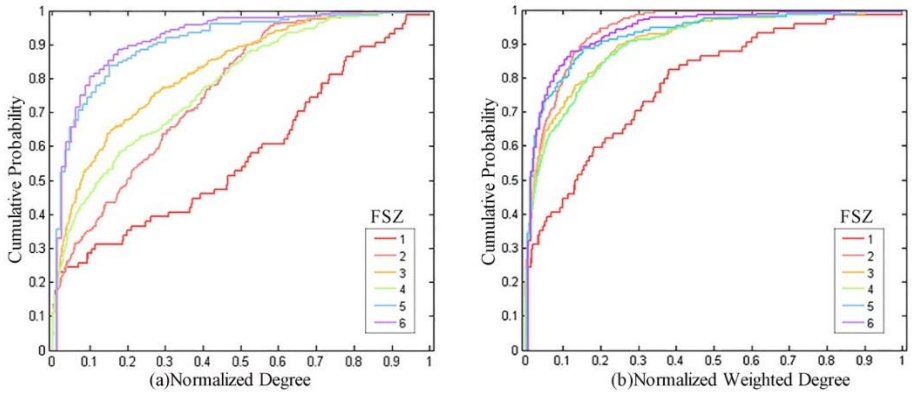

Figure 8. Cumulative probability of normalized degree (a) and normalized weighted degree (b) of the six FSZs

In Figure 8, we plot the cumulative probability curves of the normalized degrees and the normalized weighted degrees of the six FSZs. As shown in the figure, the properties of FSZ 2, 3 and 4 turn out to be similar, so do those

of FSZ 5 and 6. It could be proved that the group classification of the FSZ is reasonable. On the other hand, we could see that the cumulative probability of degrees in all FSZs increased rapidly in the beginning and then gradually slowed down. This implies that there exist a few nodes with a very high weighted degree, which dominates taxi trip flows for each FSZ. Furthermore, we detect such nodes as the hot spots of each FSZ according to the distribution of the weighted degrees. The result has been presented in Figure 9.

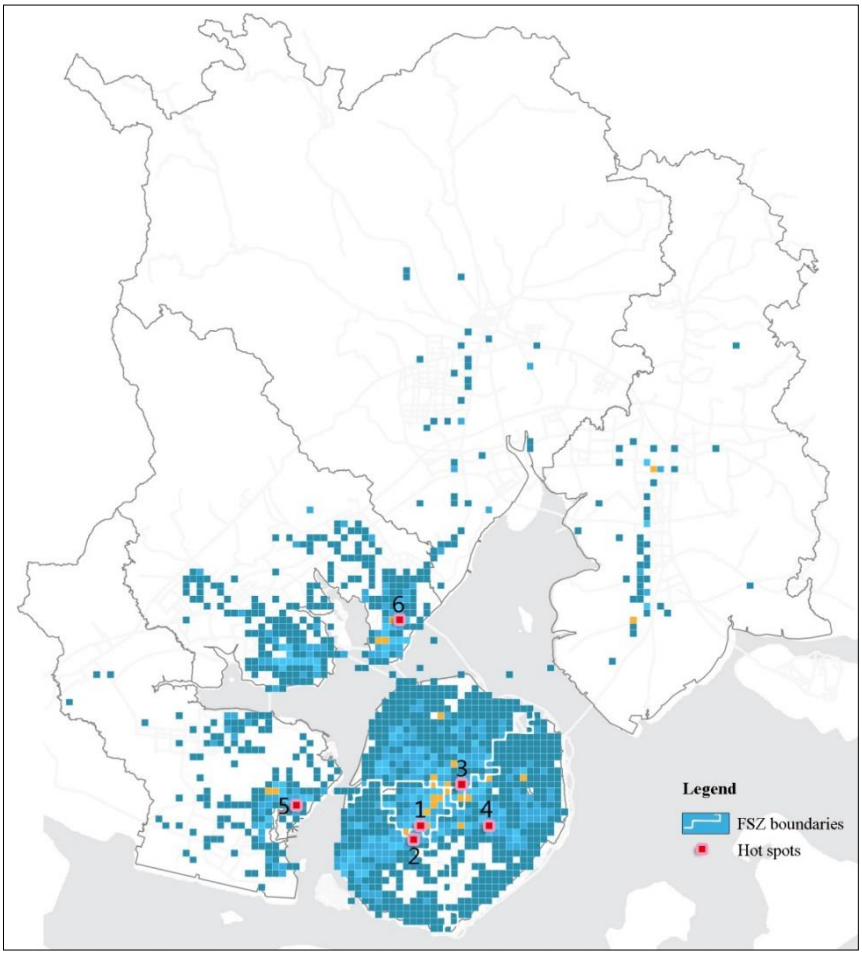

Figure 9. The spatial distribution of hot spots of each FSZ according to weighted degrees of each node

3.4 Evaluating and optimizing proposed urban land−use planning

In order to evaluate land use in the proposed FSZ, we analyze the land use planning scheme of the *Master Plan of Xiamen City (2010-2020)*. We classify the planned land use categories and summarize the percentage of each type of land in each FSZ. As shown in Figure 10, we identified that residential land accounts for a large proportion of land use in all FSZs. The trips in FSZs account for 65.1 percent of all the daily taxi trips, and the total trip mileages of all trips in these six FSZs only take up 33.6 percent of all trips. Thus, it can be inferred that the short-distance taxi trips among FSZs may be the major cause of traffic congestion.

Specifically, taking FSZ 1 (whose area is the smallest) as an example, the residential district land accounts for 49% of the total planned land within it, while most of the FSZs own an appropriate proportion of commercial and recreational districts, except FSZ 5, whose commercial proportion is relatively small. As for the proportion of official districts, a significant difference exists between Xiamen Island and the mainland areas. Clearly, the mainland area covers a relatively smaller proportion of the official district than Xiamen Island, which will probably lead to an excess of commuting heading to or out of the island. At the same time, a great number of industrial districts are distributed on the mainland areas, which necessarily require a settlement of workmen and would result in social differentiation to some extent. According to the results, it is urged that urban planners and policy makers should adjust the land use configuration in these FSZs.

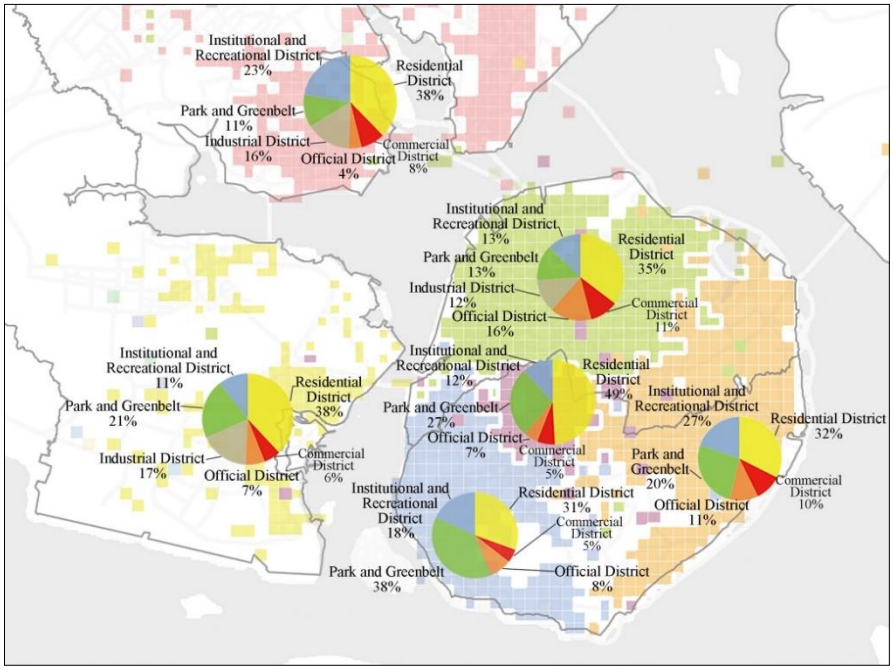

Figure 10. Comparison of planned land use conditions in the six FSZs

4. DISCUSSIONS AND CONCLUSIONS

Planning can manage individual travel behavior to some extent, however it is not able to co-ordinate individual travel behavior concretely, without considering the current situation. City blueprints depicted by traditional spatial planning based on aesthetics can rarely be realized. According to the former analysis, there is considerable disequilibrium between development on and off Xiamen Island. Clearly though, Xiamen Island has an absolute advantage in attracting people and activities, compared with the planned city center in the east of Xiamen City, which as yet is poorly developed. Given that urban planning could achieve its original goal only when the target of urban planning matches the social reality, it is therefore of great need to reconsider if the existing planning has underestimated the aggregation effect of the old city center and overestimated the effect of guiding urban development outward from the island. Considering the fact that Xiamen is a

coastal city generated from an island city, it is necessary for Xiamen to develop beyond the boundaries of the island. Therefore, it is necessary to enhance the multi-centric structure of Xiamen, which is still weak thus far.

It is in western countries that rational planning has matured, while in China, the planning industry has not yet truly accepted rational planning. However, there is an increasing number of scholars reflecting on traditional spatial planning and appealing to the application of quantitatively analyzing that which is objective and scientific in the planning progress. Moreover, access of diverse analysis platforms and availability of big data has made it inevitable, to some extent, that urban planning transforms from a traditional spatial aesthetic to a modern spatial science.

This study has built a complex network based on taxi trip data and applies the community detection method, to deeply understand urban dynamics in this research. Then, the research puts forward evaluation and suggestions for proposed urban planning on the basis of quantified urban dynamics. This research can, after all, be considered an attempt at rational planning. It provides a relevant contribution by exploring the potential of applying the taxi trip data to revelations in urban dynamics and urban planning optimization utilizing a community detection method. However, since travel by taxi is only one of the diverse ways in which people travel, limitations exist inevitably. Therefore, our future work intends to progress through the merging of multiple data sources and methods.

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Status and Problems in Location Model Research for Guidance Signage in Comprehensive Passenger Transportation Hubs

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Key words: Comprehensive Passenger Transportation Hub, Guidance Sign, Location Model, Massive Passenger Flow, Spatial Topological Network

Abstract: Internal guidance signs are critical for the normal operation of a comprehensive passenger transportation hub. In the present paper, the procedures, methods and restrictions on the development of guidance sign locations are summarized in terms of the planning and design method of guidance signs and an evaluation of guidance sign service manuals after a sorting and analysis of relevant literature. The results show that the existing location model fails to quantitatively describe the behavior characteristics of massive passenger flows and results in the spatial planning and design of guidance signage being inaccessible for many in mass passenger transit and spatial topological networks resulting from 3D hub architecture make the constraint conditions of location models more complex. Sophisticated guidance signs and location models responding to behavioral characteristics and spatial topological networks will be a trend of interest in the optimal layout of future comprehensive passenger transportation hubs.

1. INTRODUCTION

Travelers and management sectors have an increasing concern for transport hub guidance signs as information mediums for comprehensive Passenger Transportation Hubs (PT Hubs) where multiple forms of public transport merge (hereinafter referred to as a hub). The advantages and disadvantages of guidance sign location directly affect the internal traffic organization and distribution of urban PTBs. Illegible guidance sign systems may induce serious safety accidents, in particular, under massive or congested passenger flows. On February 1, 2016, China's Spring Festival travel rush combined with poor weather to cause a massive passenger flow - the time of entry to and exit from the Hongqiao Hub was delayed by several hours (Fig. 1), such as has occurred frequently in Wuhan and Guangzhou. The absence of an effective hub guidance sign added to the paralysation of the hub under the pressure of a massive passenger flow, in addition to the weather and train delays. Under the specially-dense passenger flow, the passengers inside the

hub react with urgency to reach their destination accurately and reliably using the shortest travel time or pathway according to the guidance sign system. In addition, the hub management authority also expects to provide reasonable transportation facilities, setting up optimal guidance sign locations so as to provide quality traffic services for travelers. Therefore, the planning and design of guidance signs in comprehensive PT Hubs has become a broad research hotspot in research fields related to facility location; it is a key issue for assisting the construction and operation of hubs, improving their efficiency and travel service quality.

Figure.1. Stagnated passenger flow and queue for Hongqiao railway station

The remainder of this paper is organized as follows. The basic problem concept is described in the next section, Section 2. In Sections 3 and 4, the planning method and evaluation method are described, respectively. Section 5 presents policy suggestions and future research trends of guidance signage. Finally, two critical problems are concluded in Section 6.

2. BASIC PROBLEM CONCEPT

The guidance sign system refers to a comprehensive solution to comprehensively communicate PT Hub functions, such as information transfer, visualization, identification and orientation, so as to help visitors to obtain their required information using minimal time, based on the guidance of systematic design in the spatial and information environment. Such a guidance system consists of two parts, an orientation system and a signage system. In this paper, a comprehensive guidance sign in a comprehensive PT Hub is a system pertinent to the 3D space, which consists of multiple story, a centralized passenger flow, and requiring integration across hub facilities. Therefore, understanding the service level of PT Hub guidance signs is a key research issue, particularly when taking into consideration multilayer 3D architecture, massive passenger flows and guidance signage.

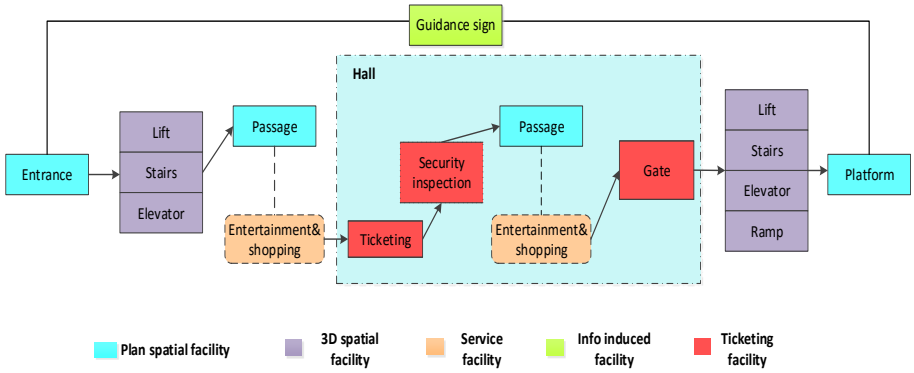

Figure 2: Schematic flow for passenger entrance

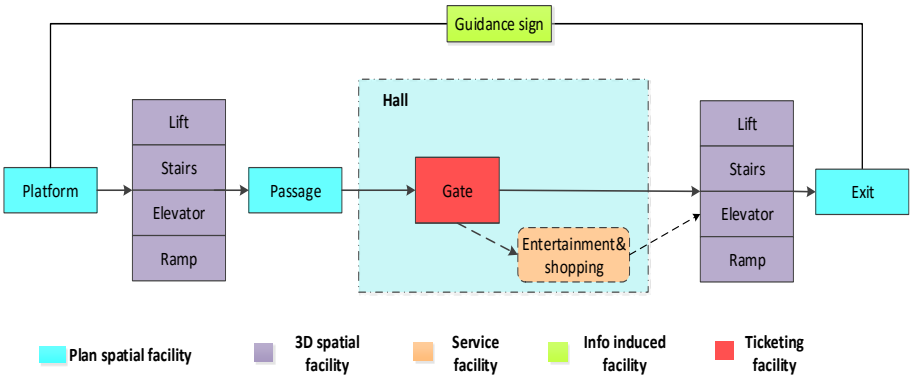

Figure 3: Schematic flow for passenger exit

Typical passenger flows inside a hub are shown in Figures 2 and 3 above. A guidance sign is effective through the entire process of a passenger's traffic behavior. The schematics mainly highlight the flows of passengers either entering or exiting a station.

3. RESEARCH ON PLANNING METHOD FOR PT HUB GUIDANCE SIGNAGE

Lynch (1960), an architect, proposed the planning of guidance signage as early as 1960. Its purpose is to allow visitors to obtain their required information in as fast a time as possible within the modern complex spatial and information environment. Patkar and N. (1984) presented the idea that a hub's service level cannot be separated from the presence of reasonable guidance and directional signage, and that the location of such signs can directly improve the accessibility of a destination and reliability of arrival time for passengers and further improve a passenger's satisfaction in a hub.

Beginning from the 1960s and '70s, traffic orientation system design started to be researched and the application of graphic symbols gradually evolved into creating flows and methodology for guidance sign planning. Lynch (1960) originally extracted urban essential elements, applying them to signage and creating the theory of guidance sign planning for application in urban planning and design. Later intensive research shifted to the importance of passenger transit signage in transport hubs and studies of signage standardization were begun. With intensive research on the streamlining of hub design, Arthur and Passini (1992) made guidance signage one of their design objectives, comprehensively taking into account the integration of people, architecture and guidance signage, determining the key design elements of guidance signage using the wayfinding method. Their results were widely accepted, modified and applied by most scholars. For example, Passini (1996) has extensively elaborated on the logical mechanism and specific application of the wayfinding method in spatial structure and interactions. This method has mostly been used for the evaluation of hub systems. In the last 10 years, Ichiro (2005) analyzed the example of Japan's Yokohama Railway Station and summarized the pedestrian traffic flow and procedures in the hub, researching the standard design and barrier-free design of guidance signage in the full process. Resultantly, the planning and design of the hub's guidance signage became richer and more refined. Mehranian et al. (2001) planned and designed air flight information signage in order to shorten passengers' wayfinding time. Chen, J. (2004) started research on public traffic guidance systems, and Xiao (2006), Mou (2006), Zhang and Yan (2007) and

others studied the spatial visual environment, hub transit guidance sign standards and spatial orientation issues. The planning and design of guidance signs became more standardized in China with the introduction of *GB_T 15566.1-2007: Guidance system for public information – Setting Principles and Requirements* and *TB10074-2007 J81-2008: Code for Design of Passenger Transport Information System of Railway Passenger Stations*.

Concurrently, research results became more abundant. For example, Bao, Dong, and Su (2009) performed a special survey on the hub guidance signage, Wu, Hu, and Chen (2011) studied visual perception based on the motion of space, and Guo, Yu, and Dong (2015) studied the planning and design issues of hub guidance signage based on human-computer interactions. In location method research, Tam (2011) proposed the multi-objective planning model based on the maximization of space incorporating level and orientation distances for the layout of a single-story hub's architectural guidance signage (Lin, Kang, & Shi, 2013). The above research results were mostly applied in the planning and design practice of transportation hubs, such as in Beijing, Shanghai, Guangzhou, Xi'an, and so on. However, the studies of existing guidance sign layout are limited within their qualitative analyses on the flows and lines of passengers inside the hub. The signage is laid out in key locations according to the standards, but a perfect optimal quantitative layout method has not yet been created. Guidance sign layout is to be further resolved and modelled based on multi-story spatial networks with visual characteristics of massive passenger flow.

4. RESEARCH ON THE EVALUATION METHOD OF SERVICE LEVEL IN HUB GUIDANCE SIGN SYSTEMS

Increasingly, scholars have intensively become concerned with and studied guidance signage, qualitatively analyzing planning and design decision-making defects based on experiences since 2007. Previous studies were mostly based on the evaluation indexes of guidance signage, based on the elements of guidance signs and the "static" evaluation of guidance sign location. Accordingly, in improving relevant evaluation index systems, scholars have refocused their research toward evaluation models based on passenger behavior, mainly in the two following categories:

The first category is based on the spatial environment and the process comparison method in which the reasonability of guidance sign locations is qualitatively evaluated based on traffic engineer experiences in the hub. The design elements (location, color, light, font, etc.) in the hub's guidance signs were compared (Jeon & Hong, 2009). Additionally, some researchers have evaluated guidance signs based on the analytic hierarchy process and satisfaction analysis method (Choi, J.-S. & Yoo, B.-B., 2006; Choi, J.-S. & Yoo, H.-B., 2006). This method depends heavily on designers' experiences as there is a lack of commonality between the layout of guidance signage across different hubs; it is difficult to isolate massive passenger flows and the visual effect mechanism of signage within the essential context of multi-story topological transport hub network architecture. Therefore, the method is insufficiently convincing and is to be refined scientifically.

The second category involves the analytic evaluation method in which the hub's passenger traffic behavior and the interactions between people and signage are resolved, and further, the service level of the guidance signs'

design elements are evaluated. Studies on the evaluation of service level focus more on the indexes, such as coverage of the guidance sign, time of passenger arrival to the destination, optimal environment for visual accessibility, etc. With the aim of setting up guidance signs as a method for resolving passenger traffic behavior, the reasonability of design elements, such as height, font and layout background, are further evaluated. For instance, Tam and Lam (2004) constructed a simplified traffic network model, introduced a passenger traffic behavior feature, and revealed the feasibility of a passenger's visual behavior in regard to the service level of guidance signs. Nevertheless, they did not study the passenger's visibility considering the spatial dimensions of a multi-story linked network. Chen, Z., Chen, and Xiong (2009) analyzed the effect of a passenger's visual zone using the visual field superposition technique and further evaluated the reasonability of guidance signs; Wu, Hu, and Chen (2011) created the streamline visibility index based on visual perception, and provide the quantitative evaluation and analysis method for the reasonability of guidance signs inside railway stations. It has been shown that research on guidance signage using the analytic method assessing passenger's visual behavior is feasible and has gradually becomes a hotspot of research. However, these methods are unclear about the flow rules of massive passenger flow inside hubs, and merely focus on single-story topological networks without any consideration of the associated multi-story spatial architectural distribution of a hub. Therefore, the accuracy of such evaluations is in doubt.

5. POLICIES FOR ISSUES AND TRENDS IN GUIDANCE SIGN RESEARCH

5.1 Existing issues in hub guidance sign research

Four existing issues may be identified by analyzing the status of research on the optimization method, as applied to hub guidance sign layout:

(1) In academic thought, most existing research is based on the issued national or industrial standards and specifications. The guidance signs are laid out at critical points in traffic lines based on single-story architectural features, signage design elements and engineer's experiences in a hub, in addition the reasonability of their distribution is qualitatively analyzed. Rare studies focused on the traffic behavior and movement rules of massive passenger flows for identifying an optimal model for multi-story spatial guidance sign layout.

(2) In research methodology, guidance sign layout based on massive passenger flows needs abstracted multi-story and visual virtual topological network models, although the optimal model of guidance sign layout depends on a common location problem. Such problem requires the resolution of basic considerations, such as of traffic geographic information technology and graph theory, however existing basic research on the key issues of spatial topological networks for multi-story hub guidance sign layout is insufficient.

(3) In the resolution of scientific issues, existing research mostly focuses on the direct transformation of guidance sign layout problems according to the *p*-center problem and *p*-median problem. However, difficulties in quantitatively describing the need of guidance signs lead to the difficulties in constructing the target functions of the above two models. Therefore, the existing research on optimal models of guidance sign layout is absent of

scientific quantitative descriptions and the resolution of passengers' needs for guidance signs.

(4) Regarding the choice of evaluation indexes for optimal guidance sign layout, existing research focuses on the evaluation index of single-story architectural guidance sign coverage, therefore leading to difficulties in quantifying needs because of the absence of traffic behavior analysis of passengers in multi-story hubs and basic research on the mechanisms of guidance signs within these environments. As a result, it is difficult to select an optimal index for guidance sign layout associated with multi-story architecture; and models of multi-story guidance sign layout are lacking in systematic research results.

5.2 Trend and policies for research of hub guidance sign location research

According to the above research status and summarization of problems, it is believed that the trend of guidance sign research in existing hubs mainly includes models of guidance sign layout under optimal efficiency, models of guidance sign layout based on the traffic behavior of massive passenger flows and models of guidance sign layout in 3D spatial networks.

(1) Layout of guidance signs combined with research on guidance sign efficiency

The efficiency concept and measurement method must be updated for assessing guidance sign placement in comprehensive Passenger Transportation Hubs in order to derive optimal results for guidance sign location: 1) the target value of guidance signs (P_E) is defined as a subjective value, which is relatively fixed and possesses less influence on the efficient improvement of guidance signs in a hub; 2) the apparent value of guidance signs (Pi) and the deviation function value of the passenger behavior ($f\left(\Delta X_i, \Delta Y_i\right)$) are determined. The resulting value has a direct influence on the efficient improvement of a comprehensive Passenger Transportation Hub, that is, the more stable the passenger behavior is, or the bigger the positive effect of factors is, the higher the system's apparent value will be. According to the factors influencing the efficiency of a guidance sign, in this paper, it is believed that the following polices can significantly improve the efficiency of a guidance sign in a comprehensive Passenger Transportation Hub:

① A guidance sign is seeable. A hub's buildings are designed in an overall manner by considering the location of a guidance sign. The inner space of a comprehensive Passenger Transportation Hub is closely related to the architectural design of the buildings. The hub's buildings must be designed integrally in space, color, light, temperature and humidity, etc., with consideration being directed particularly toward the requirement of efficient lighting, so that passengers may find signs easily; meanwhile, regarding the color of guidance signs, distinguished colors must be set alongside indications of direction and distance (see Figure 4) so that the passenger can select the most efficient pathway according to their destination's transport route.

Figure 4: Easily found guidance sign

Figure 5: Continuously-designed guidance signs

② Continuously-designed guidance sign: the signage must be set up according to the overall layout of facilities. So, the distance between guidance signs inside the hub must be determined according to the range of visibility, typically every 40-50m. When the distance is more than 20m, the posted signage can be supplemented; additionally, the continuance of guidance signs ensures that they are apparent from ground to head level (See Figure 5) in order to facilitate a passenger's ability to find their target pathway continuously and conveniently.

③ The guidance sign is adequate in size and height. The size and height of the guidance sign must be determined according to the behavior characteristics of passenger flow owing to differing passenger density and retention extent in different facilities inside a comprehensive Passenger Transportation Hub. According to the experience in a Japanese Passenger Transportation Hub, a hanging guidance sign is typically 2.2~2.5m from the floor.

④ The set guidance signs are matched to the surrounding properties. The passenger's interpretation in selecting and finding a pathway is subject to error due to the saturation of surrounding commercial and entertainment zones. Therefore, a guidance sign must be set against the surrounding properties in a manner which precludes the misguiding of a passenger selecting their pathway. Once such a problem occurs, the posted signage must be supplemented with different properties to guide a passenger to pass through the hub efficiently from that point forward.

(2) Model of guidance sign layout based on the traffic behavior of massive passenger flow

The movement rule and visual behavior of massive passenger flow and effect of guidance signs are the decisive factors for the layout of guidance signs in the hub. On the basis of mastering the movement rule and attributes of passengers inside the hub, data such as basic attributes of passengers (sex, age, destination, familiarity with hub, etc.) can be collected and surveyed, and the importance of destination facilities on different architectural floors during transit can be graded using a questionnaire to determine the weighting and missed properties of signage. Moreover, it will be an effective, feasible method for the quantitative analysis of traffic behavior of massive passenger flows and guidance sign location, to collect geometrical data (such as travel time and traffic facilities), to systematically resolve the mechanisms of movement and visual behaviors of massive passenger flows, and to abstract the traffic behavior of massive passenger flows as a visual matrix.

(3) Model of guidance sign layout in a 3D spatial network

The 3D spatial network is a typical characteristic of a comprehensive Passenger Transportation Hub. Therefore, it is significant to investigate the model of guidance sign layout by applying it to a 3D spatial network.

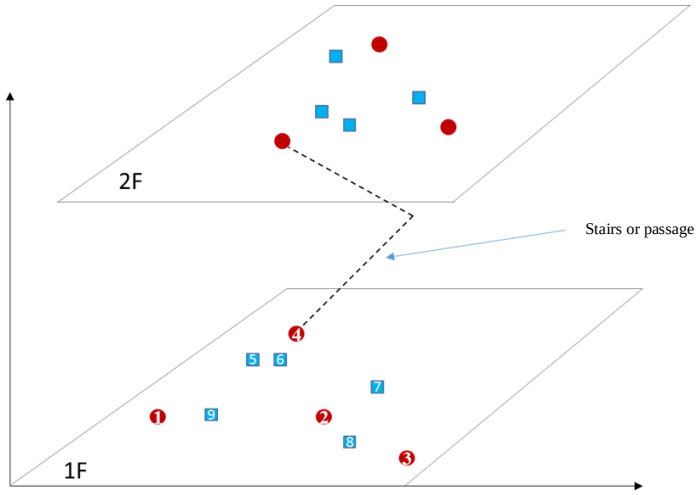

Figure 6: Conceptual drawing of 3D multi-story spatial topological network

The model research emphasis lies in resolving the difficulty of mass transit quality, regarding: 1) how to transit to and construct a multi-story spatial topological network from single-story networks (as shown in Figure 6), which will directly lead to issues in the basic science of guidance sign layout; 2) what is the story-link in a multi-story spatial topological network, and how are the measurement indexes introduced for passenger traffic behavior, also, how is the correlation of the different story indexes described? How to combine single-story networks and passenger flows, as multi-story networks and flows, is a key issue; the solution to this problem will be directly used to describe constraints within models of guidance sign location.

6. CONCLUSION

The comprehensive Passenger Transportation Hub is an important place for urban traffic and passenger transport. The high distribution level of its inner passenger flow has a direct influence on its operation. Research on the status and trend of guidance sign location models can provide an idea and method for quantitatively evaluating the advantages and disadvantages of hub guidance signs, in order to design stable, efficient and practical guidance signs in the integral Passenger Transportation Hub. The research results show that it is critical to resolve both the issues of multi-story behavior index correlation for passenger flow as well as constructing 3D spatial topological traffic networks. Both of the above issues have a direct influence on the applicability and reliability of a guidance sign location model. In addition, research on the status and policies of guidance sign location models is a necessary phase in exploring the layout of dynamic guidance signs.

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Highway Transportation Efficiency Evaluation for Beijing-Tianjin-Hebei Region Based on Advanced DEA Model

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Key words: Highway transportation, Efficiency evaluation, Advanced DEA model, Beijing-Tianjin-Hebei Region

Abstract: Regional traffic efficiency plays a key role in the development of a regional economy and its social development. How to accurately explain inherent associations and mechanisms is very significant for regional transport development and investment benefits. This paper analyses the road transport and economic development data for Beijing-Tianjin and Hebei, the Yangtze River Delta and Pearl River Delta city populations, identifies an investment and yield indicator system to effectively reflect road transport efficiency and economic development, and establishes a hybrid data envelopment analysis model based on investment indicator preferences. This model is used to compare and analyze the highway transportation efficiency of the whole Beijing-Tianjin-Hebei region and all cities in this region. The conclusion is that the highway transportation efficiency of the Beijing-Tianjin-Hebei region is less than it is in the Yangtze River Delta and Pearl River Delta urban agglomeration, and the highway transportation efficiency of cities in the Beijing-Tianjin-Hebei region are also very different, so different investment strategies should be made for the highway transportation efficiency of different cities. The research results also indicate that improvement of the regional transportation service capability not only depends on expansion of the regional transportation scale, but also depends on improvement of the regional transportation operation efficiency, and maintains support for intensified and sustainable development routes.

1. INTRODUCTION

The state pays much attention to the long-term development of the Beijing-Tianjin-Hebei region and regards the collaborative development of the Beijing-Tianjin-Hebei region as a key state strategy. Transportation is the foundation for economic development. The chairman, Xi Jinping, proposes “transportation integration as the leading field” for collaborative development of the Beijing-Tianjin-Hebei region. As an advance project, the integration of

transportation may become the first breakthrough field in collaborative development within the Beijing-Tianjin-Hebei region. As the key capital area, the total population of the Beijing-Tianjin-Hebei region is over 100 million. The Beijing-Tianjin-Hebei region is expected to drive and connect the south and north areas and become a new area of economic growth area China. However, development of the three regions has been very unbalanced for a long period and highlighted issues such as continuous, deteriorated ecological environments and unbalanced urban and town system development are faced. With an increase of the investment to transportation infrastructures from 2016, transportation infrastructure is currently under construction in these regions. How to balance the relation between investment and economic development of the transportation infrastructure is still a difficult subject. Mutual relations between regional transportation and economic development should be further evaluated in a quantitative manner.

This paper focuses on the highway transportation and economic development data of the urban agglomeration in the Beijing-Tianjin-Hebei region and the Yangtze River Delta and Pearl River Delta region, studies mutual relations between regional highway transportation and the economy, identifies the weight of the impact of the investment indices to the regional economy by using the analytic hierarchy process (AHP), establishes a highway transportation efficiency evaluation index system, and applies the data envelopment analysis (DEA) model to comprehensively evaluate the highway transportation efficiency of the whole urban agglomeration and of different cities. By analyzing the transportation highway indices in Beijing-Tianjin-Hebei and the Yangtze River Delta and Pearl River Delta regions and its development trend, this paper reasonably evaluates highway transportation operation efficiency and scale adaptation of the Beijing-Tianjin-Hebei region from the view of the investment and yield of the city's highway transportation, and provides reference for regional transportation decisions.

On the one hand, many scholars have studied the coordinated development of transportation, economy, society and the natural environment. Wang, C.-X. (2004) constructed a gray coordination model and coordination coefficient to show coordination degree of the economy and traffic by constructing an "Economy-Transportation System" and applying the system theory idea. Wang, W. et al. (2014) determined the coordination degree between the regional economy and transportation at different times, coordination relationships between different modes within regional transportation, and analyze the coordination degree between the regional economy and transportation and within the transportation system by analyzing the elastic relations of the related indices between regional transportation and the regional economy, and between different modes within the regional transportation. Wang, D. et al. (2003) simulated the future development trends of transportation and technology by using the production function method based on time sequences. They obtain comprehensive evaluation indices such as comprehensive transportation indices and resource configuration performance indices by using the indices method based on the comprehensive performance, supply and demand balance and resource configuration idea, and evaluate the degree of adaptation and coordination between transportation and economic development by using the transportation balance factor, factor analysis method and the DEA model based on the comprehensive evaluation indices.

On the other hand, the data envelopment analysis (DEA) method is mainly used to evaluate whether using multi-investment and multi-yield decision units of same type is an effective non-parametric statistics method in

technology, as it is extensively applied for efficiency evaluation in different fields and industries of the social economy. Correa (2012) analyzed current completion and efficiency conditions of the Columbian highway and railway system by using the DEA model. The research results indicate that the total average efficiency of the railway is 74.4%, and the general average efficiency of the highway is 20.56%, thereby the railway has higher efficiency in the resource configuration. Karlaftis (2004) surveyed the efficiency and benefits of the urban transportation system by using the DEA, the global efficient production function and the data from 256 transportation systems in North America over five years. The empirical data proves that the efficiency is positively correlated with the benefits. Chiu, Huang, and Ting (2011) evaluated the efficiency of transportation and the economy in China by using the value chain DEA model. Xiong, Ning, and Pan (2006) analyzed the operation efficiency of the constructed "Transportation-Economy" hybrid system by selecting multiple investment and yield indices and applying the DEA method to transportation and economy data over a 15 year period in China. Correa (2012), Jiang (2009) analyzed and evaluated the transportation system efficiency, and built the evaluation index system.

On the whole, regional traffic efficiency embodies the development of regional economies and society. With economic transformation and continuous promotion of social reforms, the relationships between the existing traffic and economy will continuously change. It is difficult to describe clearly the inherent active mechanisms between traffic efficiency and economic development based on existing research. The traditional DEA method has remarkable strengths in evaluation and research of traffic efficiency, but it is difficult to embody differences among input and output indices due to restrictions of the model. The traditional model cannot describe the maximum demand benefits under different conditions.

2. PROBLEM DESCRIPTION and modeling

2.1 Construction of investment and yield index system

Generally, factors such as investment capital, human power, material resources and functional yields of transportation services should be considered in research on highway transportation efficiency of urban agglomerations (Wang, W. et al., 2014). The mileage of the backbone highway network (km), average highway network density per persons (km/person) and highway network area density (km/km^2) represents the human power, labor and invested funds, and reflects the invested resources to the highway transportation system's efficiency within the urban agglomeration. In addition, the average GDP per person, unit area GDP (10,000 yuan/ km^2) and highway network yield of unit length (100 million yuan/km) reflect the economic benefit yields of the highway transportation efficiency system of the urban agglomeration and are key parts of highway transportation efficiency. The highway passenger transportation capacity (10,000 persons) and cargo capacity (10,000 tons) represent the functional yield of the transportation services. The urbanization rate (%) reflects the development and optimization degree of cities and also determines if the highway transportation is efficient within the urban agglomeration.

By combining the current conditions and features of highway transportation in the Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl

River Delta urban agglomerations, scientific evaluation indices, and obtainability and quantification of the indices values, the above indices are selected as the input and output indices of the model. These input and output indices can correctly reflect the contents and inherent associations of the regional highway transportation efficiency from a particular perspective. The wholly associated input and output indices compose the highway transportation efficiency evaluation system of the urban agglomeration. The input and output evaluation index system of the highway transportation efficiency of the urban agglomeration is shown in Figure 1.

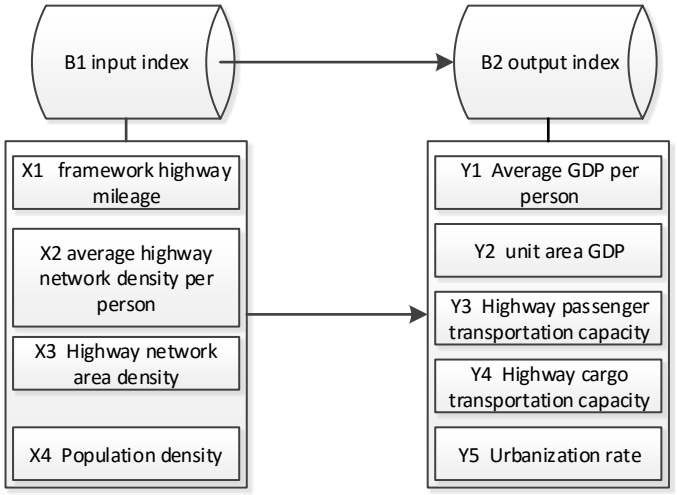

Figure 1. Evaluation index system of inputs and outputs for highway efficiency

2.2 AHP-DEA combination model based on indices reference

The DEA model mainly compares relative efficiency between evaluated organizations via mathematical programming and computing. The basic function of the DEA model is "evaluation", especially when evaluation of "relative good or bad" of multiple similar samples is studied. Parameters need not be estimated in advance, so this model is very advantageous in subjective factor avoidance, computing simplification and error reduction. The DEA model uses the actual indices value in this scheme, which avoids the standard cost of each service. This model can transform multiple investments and multiple yields to the numerator and denominator of the efficiency ratio without need of transforming them to the same money unit, so it can avoid the errors in transformation of many evaluation methods. The DEA model can clearly measure the highway transportation efficiency of the urban agglomeration and enhance objectivity and implement ability of evaluation.

However, the indices are regarded equally in terms of the evaluation of a traditional DEA model (C^2R). The differences of evaluation decisions to different indices are not considered. Based on the subjective factors of the indices preference degree, the AHP method is used to analyze the importance of the investment indices, identify the weight of the indices and establish an AHP-DEA combination model. The AHP-DEA model is used to evaluate and analyze the highway transportation efficiency of the urban agglomeration.

Assuming that each of n decision units (DMU) has m inputs (namely m input indices) and s outputs (namely s output indices), the input and output

vector of j th decision unit DMU_j are represented with X_j and Y_j, and V and U are the weight coefficients, we can get:

$$X_j = (X_{1j}, X_{2j}, \mathrm{L}\ , X_{mj})^T \tag{1}$$

$$Y_j = (Y_{1j}, Y_{2j}, \mathrm{L}\ , Y_{sj})^T \tag{2}$$

$$V = (V_1, V_2, \mathrm{L}\ , V_m)^T \tag{3}$$

$$U = (U_1, U_2, \mathrm{L}\ , U_s)^T \tag{4}$$

$X_{ij} > 0, Y_{rj} > 0, V_i > 0, U_r > 0$, $j = 1, 2, \mathrm{L}\ , m$, $i = 1, 2, \mathrm{L}\ , m$, $r = 1, 2, \mathrm{L}\ , s$.

X_{ij} indicates the i th input indices of j th decision unit. Y_{rj} indicates r th output indices of j th decision unit, each decision unit has corresponding efficiency evaluation indices as follows:

$$h_j = \frac{\sum_{r=1}^{s} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij}} \tag{5}$$

The DEA model identifies the weight by optimization to make the evaluation of a group of decision units more objective. The weight optimization aims to maximize efficiency, so the qualitative differences of the vector weights are not considered in actual problems. The system evaluation has specific requirements for input and output in some cases and certain preference is required for the weight indices, namely the expert interference. At this time, the pure DEA model cannot implement this feature well, so the APH-DEA analysis model is proposed. The input and output weight indices are ranked by certain order. Assuming that final *m* input components and *s* output components have a certain sequence, namely the preference sequence, the weight vector of the investment variant is computed by using the AHP method:

$$\omega_m = (\omega_1, \omega_2, \mathrm{L}\ , \omega_m), \qquad \sum_{i=1}^{m} \omega_i = 1 \tag{6}$$

The relative efficiency optimization evaluation mode of the DMU_0 decision unit is described as follows:

$$\max \qquad h_{j0} = \frac{\sum_{r=1}^{s} U_r Y_{rj0}}{\sum_{i=1}^{m} V_i X_{ij0}} \tag{7}$$

$$s.t. \quad \begin{cases} \dfrac{\sum_{r=1}^{s} U_r Y_{rj0}}{\sum_{i=1}^{m} V_i X_{ij0}} \le 1, \qquad j = 1, 2, \mathrm{L}\ , n \\ V_i \ge 0, \qquad i = 1, 2, \mathrm{L}\ , m \\ U_r \ge 0, \qquad r = 1, 2, \mathrm{L}\ , s \\ \omega(m, s) \ge 0 \end{cases} \tag{8}$$

h_{j0} are the efficiency evaluation indices of the decision unit, $\omega(m, s)$ is the investment and yield weight matrix. Assuming that $m = 3$, the final preference weight vector computed by AHP is $(\omega_1, \omega_2, \omega_3)$. If they are ranked as $(\omega_2, \omega_1, \omega_3)$ by descending order, it can be decomposed as $\omega_2 \ge a\omega_1$,

$\omega_1 \geq b\omega_3$. a and b depend on the final computed weights. The $\omega(m,s)$ matrix is expressed as follows:

$$\omega(m,s)=\begin{pmatrix} -a & 1 & 0 & 0 & \text{L} & 0 \\ 1 & 0 & -b & 0 & \text{L} & 0 \end{pmatrix} \tag{9}$$

The equation (2) is a fraction programming model and is difficult to solve, so it is converted to a linear programming model for the solution:

$$t = \frac{1}{\sum_{i=1}^{m} V_i X_{ij0}}, \qquad \mu_r = tU_r, \qquad \eta_i = tV_i \tag{10}$$

The model is converted to:

$$\max \quad h_{j0} = \sum_{r=1}^{s} \mu_r Y_{rj0}$$

$$s.t. \quad \begin{cases} \sum_{r=1}^{s} \mu_r Y_{rj} - \sum_{i=1}^{m} \eta_i X_{ij} \leq 0, \qquad j = 1,2,\text{L}\ ,n \\ \sum_{i=1}^{m} \eta_i X_{ij0} = 1 \\ V_i \geq 0, \qquad i = 1,2,\text{L}\ ,m \\ U_r \geq 0, \qquad r = 1,2,\text{L}\ ,s \\ \omega(m,s) \geq 0 \end{cases} \tag{11}$$

3. SIMULATION COMPUTING AND RESULT ANALYSIS

3.1 Quantification of evaluation indices

With the urban agglomerations in Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta regions as the analysis samples, based on the input and output index system in Figure 1 and the annual statistical data of the national economy and social development in different provinces, the input and output indices data are obtained as shown in Table 1:

Table 1 Data of input and output indices for urban agglomeration

DMU	Urban agglomeration	Input indices				Output indices				
		X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4	Y_5
		10^4km	km/10^4p	km/km^2	p/km^2	100 million yuan/10^4p	100 million yuan/km^2	10^4 p	10^4 tons	--
1	Beijing-Tianjin-Hebei	14.84	16.82	0.79	0.05	6.62	0.31	138646	185876	0.56
2	Yangtze River Delta	17.17	15.44	1.52	0.10	9.38	0.93	405240	542380	0.67
3	Pearl River Delta	7.51	11.58	1.34	0.12	7.69	0.89	285733	199056	0.63

Note: Until the end of 2014, p = person

Table 2 Data of input and output indices for Jing-Jin-Ji agglomeration

Item	BJ	TJ	SJZ	TS	ZJK	BD	QHD	LF	CZ	CD
Highway network Mileage (km)	21892	20000	18000	17000	20452	17100	8859	10645	12000	2483
Population (10^4 persons)	2152	1472	1050	771	435	1119	299	447	731	347
City area (km^2)	16411	11947	20235	13472	36000	22810	7812	6500	13419	39519
Highway population density (km/10^4 persons)	10.17	13.59	17.14	22.06	47.06	15.28	29.65	23.82	16.42	7.15
Highway area density	1.33	1.67	0.89	1.26	0.57	0.75	1.13	1.64	0.89	0.06
GDP	21331	15722	5100	6225	966	2050	930	2056	3133	881
Highway passenger transportation capacity (10^4 persons)	52354	42451	4076	12646	3050	12754	1883	2830	4153	2449
Highway cargo transportation capacity (10^4 tons)	25416	36879	7394	49192	4602	30888	5533	13370	5360	7242
Urbanization rate	0.86	0.78	0.56	0.56	0.49	0.43	0.51	0.53	0.47	0.45
Average highway network density per person (km/10^4 persons)	10.17	13.59	17.14	22.06	47.06	15.28	29.65	23.82	16.42	7.15
Highway network area density (km/km^2)	1.33	1.67	0.89	1.26	0.57	0.75	1.13	1.64	0.89	0.06
Population density (10^4 persons /km^2)	0.13	0.12	0.05	0.06	0.01	0.05	0.04	0.07	0.05	0.01
Average GDP per person (100 million yuan /10^4 persons)	9.91	10.68	4.86	8.08	2.22	1.83	3.11	4.60	4.29	2.54
Land average GDP (GDP/km^2)	1.30	1.32	0.25	0.46	0.03	0.09	0.12	0.32	0.23	0.02

Note1: BJ: Beijing, TJ: Tianjin, SJZ: Shijiazhuang, TS: Tangshan, ZJK: Zhangjiakou, BD: Baoding, QHD: Qinhuangdao, LF: Langfang, CZ: Cangzhou, CD: Chengdu
Note2: Until the end of 2014

3.2 Model computing and analysis

3.2.1 Data pre-processing and hot spot analysis

Based on the equation (6), Lingo software is used for computing. Based on the efficiency of Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta for the optimal solution, three group models are established. The final results are shown in Table 3. The final results are described as follows: $h=1$ and S^+ and S^- are 0 for the urban agglomeration in the Yangtze River Delta region, so the DEA is effective. $h=1$ and $S^+ \neq 0$ or $S^- \neq 0$ for the urban agglomeration in Beijing-Tianjin-Hebei and Pearl River Delta regions, so the DEA is weakly effective. Based on the results, the highway transportation efficiency of the urban agglomeration in the Yangtze River Delta is maximized, followed by the Pearl River Delta. The efficiency of Beijing-Tianjin-Hebei is minimal. The difference between the Yangtze River Delta and Pearl River Delta regions is smaller. The data indicate that the highway network area density of the Beijing-Tianjin-Hebei region is significantly lower than that of the urban agglomeration in the Yangtze River Delta and Pearl River Delta regions, and its population density is also slightly less, so the highway network has certain construction growth space.

Table 3 Total result of three urban agglomerations based on AHP-DEA model

DMU	Beijing-Tianjin-Hebei	Yangtze River Delta	Pearl River Delta
P	(1.0,0.0,0.0)	(0.0,1.0,0.0)	(0.0,0.0,1.0)
V	(0.000,0.316,3.101,0.000)	(0.000,0.000,0.000,0.000)	(0.000,0.785,0.000,0.000)
U	(0.000,0.000,0.000,0.000,25.316)	(0.000,0.000,0.000,0.000,0.000)	(0.000,10.215,0.000,0.000,0.00)
S	(1.000,1.340,1.109)	(0.518,1.000,0.880)	(1.453,1.333,1.000)
T	(1.000,1.195,1.109)	(0.343,1.000,0.367)	(0.348,1.040,1.000)
S_{ave}	0.990	1.224	0.996
T_{ave}	0.564	1.100	0.825
h	1.000	1.000	1.000

Similarly, to analyze the highway transportation and economy data in the Beijing-Tianjin-Hebei region, the final computed highway transportation efficiencies are shown in Table 4. The computing results are described as follows: $h=1$ and $S^{+}\neq 0$ or $S^{-}\neq 0$ for the final highway transportation efficiency of Beijing, Tianjin, Tangshan, Baoding and Chengde, so the DEA is weakly effective for highway transportation efficiency in Beijing, Tianjin, Tangshan, Baoding and Chengde, but the production efficiency in these cities is maximized compared to other cities. The high transportation investment is effective and the highway transportation efficiency has huge development potential in the future. $h<1$ for the highway transportation efficiency in Shijiazhuang, Zhangjiakou, Qinhuangdao, Langfang and Cangzhou. Compared to the first-class cities in Beijing-Tianjin-Hebei, the highway transportation efficiency in these cities can be further improved.

Table 4 Data of inner cities in Jing-Jin-Ji agglomeration based on AHP-DEA model

	V					*U*					
City	Highway network mileage	Highway population density	Highway area density	Population density	Average GDP per person	Land average GDP	Highway passenger transportation capacity	Highway cargo transportation capacity	Urbanization rate	h	Rank
BJ	0.0000	0.0000	4.4091	71.0000	0.0000	0.0000	0.0001	0.0000	0.0000	1.0000	1
TJ	0.0000	0.0000	0.9791	146.2115	0.0000	6.9061	0.0000	0.0000	0.0000	1.0000	1
SJZ	0.0000	0.3253	0.0000	184.0479	1.2996	0.0000	0.0000	0.0000	0.0000	0.6312	4
TS	0.0000	0.1463	3.0076	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	1.0000	1
ZJK	0.0000	0.0000	0.0000	2000.0000	0.0000	0.0000	0.0010	0.0000	11.0472	0.9459	2
BD	0.0000	0.2329	4.7778	0.0000	0.0000	0.0000	0.0002	0.0003	0.0000	1.0000	1
QHD	0.0000	0.0000	0.0000	666.6667	0.0000	19.9296	0.0000	0.0000	6.9501	0.5085	6
LF	0.0016	0.0000	0.0000	0.0000	0.8543	6.6740	0.0000	0.0000	0.0000	0.6253	3
CZ	0.0000	0.3278	0.0000	185.4552	1.3096	0.0000	0.0000	0.0000	0.0000	0.5614	5
CD	0.0000	1.2153	0.0000	110.7177	0.0000	0.0000	0.0000	0.0000	32.0513	1.0000	1

Note1: BJ: Beijing, TJ: Tianjin, SJZ: Shijiazhuang, TS: Tangshan, ZJK: Zhangjiakou, BD: Baoding, QHD: Qinhuangdao, LF: Langfang, CZ: Cangzhou, CD: Chengdu

4. DISCUSSIONS AND CONCLUSIONS

This paper analyzes the weakness of the traditional DEA(C^2R) model, establishes an AHP-DEA model, computes, and analyzes and evaluates the highway transportation efficiencies of the urban agglomerations in Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta regions. The

differences of the weight indices are not considered in the traditional DEA(C^2R) model. The evaluation results indicate that the DEA model is effective for the highway transportation efficiency of the Yangtze River Delta and Pearl River Delta regions and is weakly effective for the highway transportation efficiency of the Beijing-Tianjin-Hebei region. Based on the AHP-DEA model, the computing results indicate that the DEA is effective for urban agglomerations in the Yangtze River Delta region and is weakly effective for urban agglomerations in the Pearl River Delta and Beijing-Tianjin-Hebei region, so it is necessary to further perfect the highway transportation system and increase highway transportation development in the Beijing-Tianjin-Hebei and Pearl River Delta regions in future. The highway transportation efficiency of three urban agglomerations are ranked as Yangtze River Delta region, Pearl River Delta region and Beijing-Tianjin-Hebei region by descending order. To analyze the cities in the Beijing-Tianjin-Hebei region, the DEA is weakly effective for the cities in the Beijing-Tianjin-Hebei region (Beijing, Tianjin, Tangshan, Baoding and Chengde), so the development potential is huge. It is necessary to further perfect the highway transportation system and improve the highway transportation efficiency. The highway transportation efficiency of Shijiazhuang, Zhangjiakou, Qinhuangdao, Langfang and Cangzhou is less. The highway transportation efficiency is less than 0.7, except in Zhangjiakou. It indicates that the investment in the highway transportation infrastructure is insufficient; it is necessary to promptly improve the highway transportation facilities and improve highway transportation efficiency.

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Analyzing the Effectiveness of Policy Instruments on New Energy Vehicle Industry using Consistent Fuzzy Preference Relations

A case study in China

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Abstract: New energy vehicles (NEVs) have important implications for traffic pollution management and energy consumption. A series of industrial incentive policies have been introduced to promote the development of the NEV industry. However, the actual effects of the policies do not come up to expectations. Aiming to analyze the relationship between the policy instruments and the market acceptance of NEVs, a consistent fuzzy preference relations model is proposed to evaluate the efficiency of policies on the NEV industry. The model introduces an assessment criteria system with three criterions (industry development, technology research and development (R&D), and NEV popularization). The quantitative weights of evaluation criteria are calculated by the fuzzy preference relation. The weights indicate the significance of the factors in the development of NEVs, especially when NEVs have not been widely accepted. With the proposed model, a case study in China shows that the policy of technology R&D is the most crucial for the NEV industry in China. The policy of NEV industry development, on the other hand, is equally important. The results are hoped to give a better understanding of the relationship between government policy instruments and NEV development, the measures for enhancing the policy efficiency of NEV development.

1. INTRODUCTION

Nowadays, the concept of sustainable development with green economy, low-carbon travel and energy saving has become increasingly important and popular worldwide. It has been acknowledged that the adoption of NEVs is an effective way to reduce the dual pressures brought by energy crises and environmental protection agendas. New energy vehicles (NEVs) – vehicles using non-traditional fuels (ethanol, biogas, biodiesel) such as electric vehicles, fuel cell vehicles and hybrid electric vehicles – are of particular strategic importance for several reasons. To start with, reducing dependence on fossil fuels is one of the soundest reasons. Moreover, the debate on CO_2 emissions and other air pollutants (vehicle emission is one of the major sources of air pollution) constitutes another reason. Realizing such challenges caused by the transportation sector, NEVs have become an inevitable choice

for the sustainable development of the automobile industry in various countries. Several new propulsion measures for NEVs have emerged and already entered, or are ready to enter the market in the future. However, the development of the NEV industry does not perform up to expectations. Because of the cost disadvantages, limited driving range as well as inadequate charging facilities, the NEV industry has to overcome several obstacles in order to achieve a shift in the transportation sector. Therefore, government policy instruments are important to improve the technical level of NEVs and encourage the purchase of NEVs.

Many countries and regions, such as China, the United States and Europe, have set up goals to develop NEVs. Since 1990, the Chinese government has continuously enacted a series of regulations and support policies to promote the development of the NEV industry. In 2001, the Ministry of Science and Technology of the People's Republic of China (MOST) launched the '863 Program', a specialized electric vehicle (EV) project. It established three 'vertical' and three 'horizontal' schemes. During the last several years, China's NEV industry has begun to move from research towards commercialization and mass production. In 2008, the BYD dual-mode electric car F3DM won the approval of the Ministry of Industry and Information Technology (MIIT), which heralded a new stage of China's NEVs industrialization development. On January 24th, 2009, the Ministry of Finance with the Ministry of Science and Technology initiated the 'Ten Cities, Thousand Vehicles Program' to stimulate the adoption of NEVs (Zheng et al., 2012). In these cities, local governments encouraged using NEVs in public transportation, e.g. taxis, environmental sanitation vehicles, logistic vehicles, police vehicles, and postal vehicles. Meanwhile, an accompanying subsidy policy was also adopted to increase the sales of NEVs. By the end of 2010, most Chinese auto companies started mass production of own-brand NEVs, with many other Chinese firms investing in the industry of hybrid electric vehicles. In March 2013, the '12th Five-year Major National Innovation Base Construction Plan' put forward that new energy vehicles would be regarded as an area with high innovation and foundation advantages and be a pilot industry for the major national innovation base. In December, MIIT issued four national standards regarding electric vehicle charging interface and communication protocols, which was a huge step to perfecting China's NEVs standards system, impelling NEV pilot demonstration and promoting the coordinated development of NEVs.

In the United States, the Energy Policy Act of 1992 implemented an alternative fuel demonstration project, and identified mixtures containing 85 percent or more by volume of methanol with gasoline or other fuels as alternative fuels. In 2005, the U.S. Government decided to provide a $2000 tax deduction for all qualifying hybrid vehicles. Nevertheless, the Energy Policy Act of 2005 replaced this tax deduction with a tax credit based on an individual vehicle's emissions profile and fuel efficiency compared to equivalent gasoline vehicles from January 2006 (Diamond, 2009). Credits vary from several hundred to several thousand dollars, and phase out over time after the manufacturer sells a total of 60,000 hybrid and lean-burn vehicles (Department of Energy, 2007). Many states offer additional incentives besides the federal tax credit. Starting in 2008, Colorado provided the most generous incentive structures with credits of $2500–$6000 according to the vehicle, while several other states offer incentives valued no less than $1500 (Brad, 2010). Some states, e.g. New York, Virginia, Florida, California and Utah, allow hybrid owners to use high-occupancy vehicle lane access regardless of the number of occupants on one or more highways in the state. As of

November 2014, about half the states have established incentives and tax or fee exemptions for BEVs and PHEVs (battery or plug-in EVs), or utility-rate breaks, and other non-monetary incentives such as free parking.

European governments are also making good efforts toward achieving high market penetration of NEVs. The goals of the individual countries are mostly similar - carbon-free fleets in pollution-free cities - many different approaches to making it happen are in place (Lindquist & Wendt, 2011). In order to define the acceptable limits for exhaust emissions of new vehicles sold in EU member states, Europe legislates increasingly stringent emission standards. At the end of 2012, Euro VI emission regulations came into force. In 1995, Europe announced a green paper on its EU energy policy to actively promote diverse automotive energy and attach importance to developing hydrogen, natural gas and biofuels. In 2003, Europe released Future Prospects for European Hydrogen, and formulated the European Hydrogen Energy Roadmap. These measures forcefully promoted the industrialization and research and development (R&D) of electric vehicles and enhanced the technological competitiveness of the automobile industry. In 2008, the EU passed legislative proposals on developing a new energy vehicles draft to further support the development of the clean-energy industry. At the same time, the European Parliament passed a bill that required public departments, enterprises and so forth to purchase fuel-efficient vehicles such as electric vehicles. In 2010, the European Commission brought forward a strategy to encourage the development of clean-energy vehicles (mainly referring to electric vehicles) and fuel-efficient vehicles. This was aimed at establishing a clean, energy saving transportation system, reducing the vehicle emission pollution and promoting the use of NEVs.

Nowadays, many scholars have carried out extensive research on the technology of NEVs, promoting the development of NEVs toward pure electric vehicles. Nevertheless, as a new emergent industry, the development of NEVs greatly depends on the support of government. For example, in China, the production and sales of NEVs are influenced significantly by government policy. However, there is still a huge gap between China's NEV industry and that of foreign countries on technology development, talent reserves and industrial cooperation.

Besides the NEV technology, previous research also focused on the policy instruments of the NEV industry. According to the literature review, policy guidance and planning played a vital role in the growth of the NEV industry (Yuan, Liu, & Zuo, 2015). Stimulated by the policy shift, electric vehicle production has increased considerably, thereby contributing 23% and 44% of total NEV production in 2010 and 2011, respectively (Gong, Wang, & Wang, 2013). Nevertheless, the NEV industry faces significant challenges related to the industrial chain, social factors and technologies. The Japanese Government has adopted a comprehensive strategy including R&D, demonstration programs and market support guided by long-term strategic plans. The results show that flexibility, adaptability and cooperation in terms of technical choice is necessary in policy. Three alternative policy support measures, namely an up-front price support, a CO_2 tax, and an increase in the fuel consumption tax for ICEs (internal combustion engines), could promote NEVs, and NEVs will be cost-competitive with ICEs if projected production volumes and thus economies of scale are reached (Gass, Schmidt, & Schmid, 2014). Besides these alternative policy support measures, market support, even in the early phases of development, is an important complement to R&D for gaining experience and building markets (Åhman, 2006). Policy intending to give NEVs a foothold in the market should not only focus on mainstream

consumers but also should focus on niche markets - especially car-sharing and postal fleets - and early adopters, including green consumers (Green, Skerlos, & Winebrake, 2014). In China, the marketing strategy of enterprise and consumer behavior is influenced profoundly by government policy (Zhang, X. et al., 2013). Meanwhile, government policy has a positive adjustment function in the economic benefits of NEVs, consumers' purchase intentions and acceptable pricing. It further enhances the environmental protection spirit of consumers and meets their psychological needs. Government incentive policies, especially monetary incentives, impose a marked influence on the sales of NEVs. New technology developed by enterprises and research institutions under the encouragement of government could effectively reduce the cost of NEVs and make it more attractive (Liu & Kokko, 2013). The consumers' willingness to buy NEVs and the purchase time is deeply affected by government policy (Zhang, Y., Yu, & Zou, 2011).

The mentioned research mainly examined the effect of government policy through the NEV industry and consumer perspectives. However, it is important to analyze the effect of policy on the NEV industry from the perspective of the macro analysis of policy itself. With the aim of studying the effectiveness of policy instruments on the NEV industry and analyzing improvements for the policy efficiency of NEV development, this paper proposes an evaluation framework for NEV policy based on consistent fuzzy preference relations (CFPR). A case study of Chinese NEV policy evaluation is performed to verify the proposed method. The results are hoped to give a better understanding of NEV policy efficiency and policy measures for NEV development. The remaining part of the paper is organized as follows: Section 2 will introduce the consistent fuzzy preference relation as the evaluation method, Section 3 will propose the evaluating criteria for NEV policy efficiency, then, a case study in China is conducted to verify and validate the evaluation index and method, and finally, some conclusions and future works will be discussed in the last section.

2. CONSISTENT FUZZY PREFERENCE RELATIONS

Saaty (1980) proposed the analytic hierarchy process (AHP) for solving multi-criteria decision problems, which included many comparisons of criteria. In an AHP, a questionnaire needs to contain questions for every grouped *n*-criterion pairwise comparison. However, if the *n* increases, or such *n*-criterion group increases, the number of pairwise comparisons also increases. This may cause experts mental fatigue or inconsistent interpretations due to so many questions and comparisons. In the case of inconsistencies, questionnaires have to be refilled again, which results in inefficiency and the wasting of time.

Consistent fuzzy preference relations (CFPR) can avoid the aforementioned problem effectively. CFPR is used to establish the pairwise comparison matrices and construct the decision matrices of pairwise comparisons using additive transitivity. Experts only need to answer n-1 comparisons. The remaining (n-1)(n/2-1) values of pairwise comparisons of each n-criterion can be derived by using the CFPR method, which only involves simple calculations, and the procedure guarantees a consistent result in comparisons.

2.1 Preference relations

Preference relations (PR) enable experts to give values for a set of criteria and a set of alternatives. The value expresses the preference degree of the first alternative over the second alternative. Fundamentally, two kinds of preference relations are applied in the decision-making problems: multiplicative preference relations and fuzzy preference relations.

Multiplicative preference relations (Chiclana, Herrera, & Herrera-Viedma, 1998): A multiplicative preference relation A on a set of alternatives X is represented by a matrix A. A can be obtained by

$$A \subseteq X \times X, A = (a_{ij}), \quad \forall i, j \in \{1, \mathrm{K}, n\} \tag{1}$$

where a_{ij} is the preference ratio of alternative x_i over x_j. Saaty (1980) suggests measuring a_{ij} using a ratio scale from 1 to 9 scales. When $a_{ij} = 1$ the indifference between x_i and x_j; $a_{ij} = 9$ represents that x_i is absolutely preferred to x_j; $a_{ij} > 1$ denotes that x_i is preferred to x_j. The preference relation *A* is typically assumed to be a multiplicative reciprocal, given by

$$a_{ij} \cdot a_{ji} = 1, \quad \forall i, j \in \{1, \mathrm{K}, n\} \tag{2}$$

Fuzzy preference relations (Chiclana, Herrera, & Herrera-Viedma, 1998): a fuzzy preference relation *P* on a set of alternatives *X* is a fuzzy set denoted by the product set $X \times X$ with a membership function

$$\mu_p : X \times X \to [0,1] \tag{3}$$

The preference relation is represented by the $n \times n$ matrix, where $p_{ij} = \mu_p(\mathrm{x}_i, \mathrm{x}_j) \ \forall i, j \in \{1, \mathrm{K}, n\}$. Herein, p_{ij} indicates the fuzzy preference ratio of the alternative x_i to x_j when $p_{ij} = 1/2$ indicates that no difference exists between x_i and x_j, $p_{ij} = 1$ means that x_i is absolutely preferred to x_j, and $p_{ij} > 1/2$ implies that x_i is preferred to x_j. In this case, the fuzzy preference matrix *P* is usually assumed to be an additive reciprocal, that is,

$$p_{ij} + p_{ji} = 1, \quad \forall i, j \in \{1, \mathrm{K}, n\} \tag{4}$$

However, inconsistency may exist in traditional decision matrices. To solve this problem, Herrera-Viedma et al. (2004) proposed that the consistent fuzzy preference relations (CFPR) could be used to construct the decision matrices of pairwise comparisons based on additive transitivity. Three important propositions in CFPR are described as follows.

2.2 Consistent fuzzy preference relations

Proposition 1. Suppose a set of alternatives, $X = \{x_1, \mathrm{K}, x_n\}$, associated with a reciprocal multiplicative fuzzy preference relation $A = (a_{ij})$ with $a_{ij} \in [1/9, 9]$. Then, the corresponding reciprocal fuzzy preference relation, $P = (p_{ii})$ with $p_{ii} \in [0,1]$ associated with *A* is defined as $P = g(A)$, i.e.,

$$p_{ij} = g(a_{ij}) = \frac{1}{2}(1 + \log_9 a_{ij}) \tag{5}$$

where *g(*)* is a transformation function which transforms a reciprocal multiplicative preference relation matrix into a preference relation. $\log_9 a_{ij}$ is considered because a_{ij} is between 1/9 and 9. When a_{ij} is between 1/5 and 5, $\log_5 a_{ii}$ is used.

Proposition 2. For a reciprocal fuzzy preference relation $P = g(A)$, where $P = (p_{ii})$, the following statements are equivalent.

$$p_{ij} + p_{jk} + p_{ki} = \frac{3}{2}, \quad \forall i, j, k \tag{6}$$

$$p_{ij} + p_{jk} + p_{ki} = \frac{3}{2}, \quad \forall i < j < k \tag{7}$$

Proposition 3. For a reciprocal fuzzy preference relation, $P=(p_{ij})$, the following statements are equivalent.

$$p_{ij}+p_{jk}+p_{ki}=\frac{3}{2}, \qquad \forall i<j<k \tag{8}$$

$$p_{i(i+1)}+p_{(i+1)(i+2)}+\mathrm{L}\ +p_{(j-1)j}+p_{ji}=\frac{j-i+1}{2}, \qquad \forall i<j \tag{9}$$

Following **Proposition 3,** we can structure a consistent fuzzy preference relation P on $X=\{x_1,x_2,\mathrm{K}\,,x_n,n\geq 2\}$ from n-1 preference values $\{p_{12},p_{23},\mathrm{K}\,,p_{(n-1)n}\}$.

A decision matrix with values not in the interval [0, 1], but in an interval [-k, 1+k], k>0, can convert the obtained values with a transformation function that preserves reciprocity and additive consistency. The transformation function f(x) is given in the following steps (Herrera-Viedma et al., 2004):

Step 1 Compute the set of preference values for B as

$$B=\{p_{ij},i<j\wedge p_{ij}\notin\{p_{12},p_{23},\mathrm{K}\,,p_{(n-1)n}\}\}$$

$$p_{ii}=\frac{j-i+1}{2}-p_{i(i+1)}-p_{(i+1)(i+2)}-\mathrm{L}\ -p_{(j-1)j}$$

Step 2 Compute the value k

$$k=\left|\min\{B\,\mathrm{U}\{p_{12},p_{23},\mathrm{K}\,,p_{(n-1)n}\}\}\right|$$

Step 3

$$p=\{p_{12},\mathrm{K}\,,p_{(n-1)n}\}\,\mathrm{U}\,B\,\mathrm{U}\{1-p_{12},\mathrm{K}\,,1-p_{(n-1)n}\}\,\mathrm{U}\neg\mathrm{B}$$

Step 4 The transformation function f(x) is

$$f:[-k,1+k]\rightarrow[0,1],\ f(x)=\frac{x+k}{1+2k},k>0$$

2.3 Evaluation of the weights of criteria

After the fuzzy preference relation matrices, $P=(p_{ij})$, of pairwise comparisons is constructed, the weight of each factor is ready for calculation. The average preference, f_i, of each criterion in the main criteria can be computed by the following

$$f_i=\frac{1}{n}\sum_{j=1}^{n}p_{ij} \tag{10}$$

where p_{ij} is the value in the preference relation matrix P and n is the number of criteria. The weight w of each criterion can be defined as follows

$$w_i=\frac{f_i}{\sum_{i=1}^{n}f_i} \tag{11}$$

2.4 Method discussions

The CFPR method in the AHP hierarchy is more convenient than the traditional AHP method. Firstly, it is easier to compute the relative weights of each main criteria and sub-criteria using the CFPR method. The CFPR method does not need to consider any complex integration, differentiation or simultaneous equations. Secondly, the CFPR process enables researchers to effectively reduce the pairwise comparison frequency. For instance, the CFPR

method only needs to perform 2+7+5+4=18 pairwise comparisons, whereas the AHP method must perform $C_2^3 + C_2^8 + C_2^6 + C_2^5 = 56$ pairwise comparisons. And obviously, the CFPR method spends less time in comparison than the AHP method. Thirdly, the CFPR method ensures consistency. Inconsistency always occurs during comparison with traditional AHP if each group has a number of criteria to compare. Nevertheless, the consistency of decision matrices can be guaranteed by CFPR.

3. CRITERIA FOR EVALUATING NEV POLICY

New energy vehicle policy, as a public policy, is crucial to consider in the process of designing an evaluation system for NEV policy. NEV policy is a complex system and a large number of factors need to be considered before the evaluation. Whether the evaluation system is reasonable or not will determine the result of the evaluation directly. In the premise of following the principle of comprehensiveness, comparability, independence, guidance and quantification, great attention is paid to guarantee the clarity of the criteria selection and the gradation of the criteria structure, and to establish a perfect, scientific and reasonable evaluation system. According to the general procedure for public policy making, such as policy formulation and implementation, a NEV policy evaluation criteria system is established. It contains the following three aspects: NEV industry development criterion, NEV technology research and development criterion, as well as NEV application and popularization criterion.

The Criterion A (NEV industry development criterion) mainly focuses on industry development policy, which is the base of NEV industry development. The scientific, feasibility and comprehensiveness of the industry development policy provides a good condition for the healthy development of the NEV industry. The Criterion A contains eight sub-criteria as follows (see Table 1 below). The standard system includes battery specification, charging station (pile), standards of charging facilities, standard of key components, etc. The access system supports social capital and companies with technology innovation capability to develop and manufacture NEVs (Brown, Pyke, & Steenhof, 2010). An industry development roadmap provides a development orientation for the NEV industry. An industrial R&D subsidy is necessary to supply effective capital support for companies and is significantly and positively correlated to a country's NEV market share (Sierzchula et al., 2014). NEV infrastructures contain charging stations, charging piles, parking lots, etc. Infrastructures are very important for the development of the NEV industry because NEV industrialization needs the support of infrastructure.

The Criterion B (NEV technology research and development criterion) pertains to the core technology of NEVs. The core technology of NEVs, including the technology of key parts and the technology of related infrastructure, is a vital factor that constrains the development of the NEV market. Only technical breakthroughs can drive ordinary consumers to purchase NEVs. The Criterion B has six sub-criteria demonstrated as follows (see Table 1). A charging station (pile) is the charging place for NEVs when the battery power is low. The charging time in express charge mode and slow charge mode are two of the most important factors influencing consumer decisions to buy NEVs. Battery technology determines battery energy storage ability and service life, which affects NEV mileage. About the NEV power system, there are several factors that should be taken into consideration, e.g. the type of NEV, charging time, charging characteristic and charging mode.

With the development of NEV technology, it is necessary to establish a convenient integration power system to efficiently manage the power supply process in generation, transmission and distribution. Therefore, other new technology, such as intelligent transportation technology and connected vehicles, also play an important role in the development of the NEV industry.

The Criterion C (NEV application and popularization criterion) mostly concerns the widespread use of NEVs. For now, most consumers adopt a wait-and-see attitude to NEVs. The application and popularization of NEVs is an effective strategy to eliminate the wait-and-see attitude of consumers toward buying NEVs. The Criterion C includes five sub-criteria illustrated as follows (see Table 1). Demonstration effect means drawing the attention of the consumer through presenting NEVs as taxis, buses, postal vehicles and so on (Zheng et al., 2012). Consumer subsidy is a general way to encourage consumers to purchase NEVs. The subsidy standards always differ depending on driving mileage. Consumer cognition and acceptance levels reflect consumers' preferences for NEVs, which is most likely to affect consumers' choice for NEVs (Zhang, Y., Yu, & Zou, 2011). Government procurement is an effective manner to promote NEVs when NEVs are not widely accepted by consumers.

The main criteria and the sub-criteria for evaluating NEV policy are listed in Table 1.

Table 1 The AHP model of New Energy Vehicle Industry Policy

Notation	Main criteria (Level 1)	Notation	Sub-criteria (Level 2)
A	NEV industry development criterion	A1	industry standard system and access system
		A2	technological achievements industrialization and marketization
		A3	industry development roadmap
		A4	energy consumption structure
		A5	industrial tax preference
		A6	industrial R&D subsidy
		A7	infrastructure
		A8	business model
B	NEV technology research and development criterion	B1	charging station (pile) technology
		B2	technical level of total vehicle
		B3	battery technology
		B4	power system technology
		B5	intelligent technology
		B6	connected vehicle technology
C	NEV application and popularization criterion	C1	demonstration effect
		C2	consumer tax preference
		C3	subsidy for NEV purchase
		C4	consumer cognitive and acceptable level
		C5	government procurement

4. CASE STUDY

This paper summarized some influential factors according to the AHP hierarchy mentioned in aforementioned literature. The sample data were obtained from six NEV policy experts. In this example, the entire procedure for constructing a decision matrix is shown as follows:

Step 1 According to Proposition 1, the results of the experts' scores, expressed by linguistic variables, are transferred into Saaty's scale as listed in Table 2 (below) for all the 22 criteria. Tables 3–6 show the experts' scores.

Step 2 Use Eq. (5) to transfer each expert's scores into raw scores and get the initial decision matrices. The rest of the decision matrices values can be obtained by using Propositions 1 and 3.

Step 3 Taking into account each expert's views, compute the average fuzzy preference relation of each expert and regard it as the basis of calculating each criterion weight. The complete decision matrices of main criteria and sub-criteria are summarized in Tables 7–10.

Step 4 By using Eq. (10) and Eq. (11), the average preference and the weight of every criterion and sub-criteria can be acquired. The results are shown in the columns 'average' and 'weight' in Tables 7–10 respectively. The column 'rank' in Tables 7-10 represents the degree of preference. The larger the weight, the higher rank.

Table 2 Degree of relative importance between two criteria

Definition	Degree of relative importance
Equally important	1
Moderately important	3
Strongly important	5
Very strongly important	7
Absolutely important	9

Table 3 Preference relation matrix for pairwise comparison of main criteria

	E1	E2	E3	E4	E5	E6
A	1/3	1/3	1	1/5	1/3	1
B	3	5	3	3	5	3
C						

Table *4* Preference relation matrix for pairwise comparison of Criterion A

	E1	E2	E3	E4	E5	E6
A1	1/3	1/3	1/5	1/5	1	1/3
A2	3	5	5	7	3	5
A3	1/3	1/7	1/3	1/5	1/5	1/3
A4	3	3	3	3	5	3
A5	1	3	3	3	1	3
A6	1/5	1/3	1/5	1/3	1/3	1/5
A7	7	7	5	5	7	5
A8						

Table 5 Preference relation matrix for pairwise comparison of Criterion B

	E1	E2	E3	E4	E5	E6
B1	3	5	5	7	5	3
B2	1/5	1/3	1/3	1/3	1/7	1/5
B3	3	5	5	3	3	5
B4	3	3	3	7	5	3
B5	1	3	3	5	3	1

Table 6 Preference relation matrix for pairwise comparison of Criterion C

	E1	E2	E3	E4	E5	E6
C1	3	5	5	3	5	3
C2	1	1/3	1	1/3	1/3	1

C3	1/3	1/5	1/7	1/5	1/3	1/3
C4	5	7	3	5	5	3
C5						

Table 7 Complete comparison matrix and rank of main criteria

	A	B	C	Average	Weight	Rank
A	0.500	0.357	0.653	0.503	0.335	2
B	0.643	0.500	0.796	0.646	0.431	1
C	0.347	0.204	0.500	0.351	0.234	3

Table 8 Complete comparison matrix and rank of Criterion A

	A1	A2	A3	A4	A5	A6	A7	A8	Average	Weight	Rank
A1	0.500	0.331	0.615	0.364	0.587	0.744	0.499	0.831	0.559	0.140	3
A2	0.669	0.500	0.785	0.534	0.756	0.913	0.669	0.999	0.728	0.182	1
A3	0.385	0.215	0.500	0.249	0.471	0.628	0.384	0.715	0.443	0.111	6
A4	0.636	0.466	0.751	0.500	0.723	0.879	0.635	0.966	0.695	0.174	2
A5	0.413	0.244	0.529	0.277	0.500	0.657	0.412	0.744	0.472	0.118	5
A6	0.256	0.087	0.372	0.121	0.343	0.500	0.256	0.587	0.315	0.079	7
A7	0.501	0.331	0.616	0.365	0.588	0.744	0.500	0.831	0.560	0.140	3
A8	0.169	0.001	0.285	0.034	0.256	0.413	0.169	0.500	0.228	0.057	8

Table 9 Complete comparison matrix and rank of Criterion B

	B1	B2	B3	B4	B5	B6	Average	Weight	Rank
B1	0.500	0.696	0.523	0.699	0.875	0.999	0.716	0.239	1
B2	0.304	0.500	0.327	0.504	0.680	0.804	0.520	0.173	3
B3	0.477	0.673	0.500	0.676	0.852	0.977	0.692	0.231	2
B4	0.301	0.496	0.324	0.500	0.676	0.801	0.516	0.172	4
B5	0.125	0.320	0.148	0.324	0.500	0.625	0.340	0.113	5
B6	0.001	0.196	0.023	0.199	0.375	0.500	0.216	0.072	6

Table 10 Complete comparison matrix and rank of Criterion C

	C1	C2	C3	C4	C5	Average	Weight	Rank
C1	0.500	0.815	0.723	0.414	0.765	0.643	0.257	2
C2	0.185	0.500	0.408	0.099	0.449	0.328	0.131	5
C3	0.277	0.592	0.500	0.191	0.541	0.420	0.168	3
C4	0.586	0.901	0.809	0.500	0.851	0.729	0.292	1
C5	0.235	0.551	0.459	0.149	0.500	0.379	0.152	4

Table 7 shows that the rank of main criteria is B (NEV technology research and development criterion) > A (NEV industry development criterion) > C (NEV application and popularization criterion), which reveals the opinions of experts on NEV policy. The result indicates that NEV technology research and development criterion is the most important factor in NEV policy. NEV technology includes battery technology, power system technology, charging technology, etc. Technology research and development is the core issue for the NEV industry and the foundation for its development. Hence, NEV policy should pay more attention to technology research and development of NEVs. NEV industry development criterion is another key criterion. Many countries in the world take NEV industry development into account as a part of a national strategy, establishing and implementing incentive policies to support NEV R&D. The difference in NEV R&D policy between various countries is the priority of the research area. For instance, Japan makes industrial competitiveness its first target. Therefore, Japan focuses on developing three kinds of electric vehicle: Plug-in Hybrid, Pure Electric and Fuel Cell. The United States pays more attention to energy conservation and emissions reduction. As a result, Extended Range Electric Vehicles and Pure Electric Vehicles are given priority in the process of industry development.

In the sub-criteria of NEV industry development criterion (Criterion A), A2 > A4 > A1 = A7 > A5 > A3 > A6 > A8 (corresponding respectively to

technological achievements in industrialization and marketization, improving energy consumption structure, industry standard system and access system, infrastructure, industrial tax preference, industry development roadmap, industrial R&D subsidy, and business model) as shown in Table 8. Industrialization and marketization of technological achievements has the biggest impact. Research of NEVs is conducted in universities and scientific research institutions. Most results of previous research remain in the laboratory stage, which lacks industrialization, particularly regarding the power system, battery and other key parts. The result demonstrates that policy has to encourage companies and research institutes to use new technology to improve the performance of NEVs, which is an important factor to expand the NEV market. Improving energy consumption structures requires reducing dependence on petroleum resources and increasing the use of solar energy, wind energy, hydropower and other renewable energy sources. Moreover, improving the consciousness of the people, to encourage them to use green energy is also a vital step. Policy makers should focus on providing infrastructure for the large-scale production of NEVs. In addition, since infrastructure is strongly related to NEV ownership, different kinds of infrastructure should be provided according to different usage modes and it should be made sure that the speed of infrastructure construction and NEVs popularization are consistent (Sierzchula et al., 2014). Other criteria such as industry standard systems and access systems, industry development roadmaps and industrial tax preferences are also situated in relatively upper ranks cannot be ignored when formulating policies.

According to Table 9, the rank of the sub-criteria of NEV technology research and development criterion (Criterion B) is B1 > B3 > B2 > B4 > B5 > B6 (corresponding respectively to charging station (pile) technology, battery technology, technical level of total vehicle, power system technology, intelligent technology, connected vehicle technology). According to the result, charging station (pile) technology ranks the top. The charging station (pile) technology is closely related to charge time, construction cost, etc. Consumers want a charge time as short as possible, as well as to charge their vehicles anytime and anywhere. Battery technology of NEVs is another important criterion because it determines the driving mileage of NEVs. The battery technology is the most crucial criterion that consumers always take into consideration, as it is the evaluating standard when buying an NEV. Improving whole vehicle technology could shorten product development periods, reduce costs and enhance competitiveness. It is beneficial to improve NEV industry competitiveness. The other three criterions, power system technology, intelligent technology and vehicular networking technology, are also critical for NEV technology research and development.

5. CONCLUSIONS

In this paper, the consistent fuzzy preference relations (CFPR) are introduced to evaluate the efficiency in NEV policy, which includes three main criteria. According to CFPR in AHP structures, it is easy to construct the multi-criteria decision matrices and to evaluate the significance of each criterion of NEV policy. The policy efficiency can be directly evaluated with the weights calculated using expert scores. The process of calculation is easy and simple. Important information can be acquired from the evaluation results for use by policy makers in future practice. According to the weights in the proposed model, the most important main criterion is the NEV technology

research and development criterion. Nowadays, NEVs are limited by disadvantages such as battery capacity and driving range. Many key technologies of NEVs, especially power battery technology, fuel cell technology and hybrid energy management systems, are technical difficulties all over the world. It is difficult to achieve a breakthrough in a short time, hence policy makers need to introduce policies focusing on technology R&D to encourage universities, research institutions and enterprises to overcome technical obstacles. Certainly, the other two main criterions should also receive enough attention.

In the sub-criteria, charging station (pile) technology, battery technology of NEVs, technological achievements for industrialization and marketization, improving energy consumption structure, infrastructure, consumer cognition and acceptance levels, demonstration effect and consumer subsidies exert an important influence on the growth of the NEV industry. These criteria constitute aspects such as technology, marketing, consumption, infrastructure and subsidies. However, whether consumers accept NEVs still depends on the economy of NEVs, the convenience of infrastructure and services, encouragement policies, as well as the cognition of consumers. Policy makers should consider these aspects when formulating policies. The development and popularization of NEVs needs powerful support from the government. In this paper, as an example, only several professionals' opinions were collected to estimate and verify the model. In reality, NEV user perspectives are important to improve NEV technology effectiveness, and their preferences are useful to estimate the model. Therefore, the data sample will be enlarged in future work to obtain more instructive results.

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A Comparative Study on the Present Government Procurement Act and Act for Promotion of Private Participation in Infrastructure Projects in Taiwan

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Key words: Government Procurement Act (GPA), Act for Promotion of Private Participation in Infrastructure Projects (PPP)

Abstract: In Taiwan, government staff, judicial officers and private institution owners should avoid erroneously misapplying the Government Procurement Act (GPA) and the Act for Promotion of Private Participation in Infrastructure Projects (PPP). This study examined the literature and conducted a comparative analysis of the legislation processes related to the Act for Promotion of Private Participation in Infrastructure Projects and the Government Procurement Act. The differences between these two Acts, as well as the government's promotion of private participation in infrastructure projects, were explored by investigating the spirit of the laws, open procedures, security measures, private sector participation and measures that promote public interest and prevent fraud. In conclusion, the historical background, legislative purpose, implementation procedures, transparency and confidentiality regulations are found to be fundamentally different between the two Acts. Because of this, executives should avoid erroneously misapplying laws.

1. RESEARCH BACKGROUND AND PURPOSES

When formulating national infrastructure plans, the government must consider how to prevent fraud and promote public interest. If fraud prevention measures are strict, then civil servants tend to perform their duties rigorously and are likely to take on fewer tasks in order to avoid making mistakes; however, infrastructure developments may be delayed and the use of public space may become inefficient. By contrast, if promoting public interest is the main focus, then risk management is disregarded and the social benefits of infrastructure development are not maximized. Therefore, developing a system for promoting public interest and preventing fraud simultaneously is crucial to the promotion of national infrastructure development.

In Taiwan, despite previous governments allocating large budgets to developing national infrastructure, they were ineffective in supervising procurement, bidding and compliance procedures, resulting in low-quality public works. Some civil servants have been subjected to judicial investigations and prosecutions because of conflicting interests. Therefore, to establish an open and fair procurement procedure and to enhance procurement

efficiency, the Executive Yuan promulgated the Government Procurement Act in 1998, in which procurement regulations were stipulated (including regulations for bid rigging and bid collusion) to prevent corruption, minimize poor budgetary spending and improve the quality of public works.

Infrastructure developments are typically undertaken to stimulate economic growth. Although the government is responsible for such developments, private funds can be acquired and professional technologies can be introduced by adopting a user-pay system to facilitate infrastructure development and to ease governmental financial pressure. Therefore, to enhance the quality of public services and to stimulate socioeconomic development, the Act for Promotion of Private Participation in Infrastructure Projects was enacted in 2000. Through private institutions' participation in public infrastructure operations, private institutions are independently liable, effectively responsible, for the performance of such operations and share their profits with the government to improve people's quality of life, achieving a beneficial outcome for the government, private institutions and the public.

In Taiwan, national infrastructure development is undertaken in accordance with the 1998 Government Procurement Act and the 2000 Act for Promotion of Private Participation in Infrastructure Projects. Before the Act for Promotion of Private Participation in Infrastructure Projects was enacted, public–private partnerships in infrastructure development were conducted in accordance with Article 99 of the Government Procurement Act, which states that companies (i.e., suppliers) who are qualified to develop infrastructure related to transportation, energy, environmental protection and tourism shall be selected by the competent authority in accordance with this article, unless provided for by other regulations. Accordingly, determining which Act should be applied when commissioning infrastructure developments is debatable. Governmental staff, judicial officers and private institution owners have often mistakenly applied the Government Procurement Act for the Act for Promotion of Private Participation in Infrastructure Projects. Furthermore, the Act for Promotion of Private Participation in Infrastructure Projects has frequently been confused with the Government Procurement Act, and the spirit of these laws has frequently been misused (Division for Promotion of Private Participation, 2006a; Public Construction Commission, 2007).

Article 2 of the Act for Promotion of Private Participation in Infrastructure Projects states that this Act prevails when promoting private sector participation in infrastructure projects. Therefore, the government must evaluate which Act their plans should be implemented in accordance with; the government should clearly define their plans in order to promote public interest and prevent fraud.

2. RESEARCH METHODS

This study examines the literature and conducts a comparative analysis of the legislation processes related to the Act for Promotion of Private Participation in Infrastructure Projects and the Government Procurement Act. The differences between these two Acts as well as the government's promotion of private participation in infrastructure projects were explored by investigating the spirit of the laws, open procedures, security measures, private sector participation and measures that promote public interest transparency and prevent fraud.

3. EVOLUTION OF THE GOVERNMENT PROCUREMENT ACT

Before the Government Procurement Act was enacted, procurement for public works was performed in accordance with the Enforcement Rules of the Audit Act, the Ordinance Concerning Inspection Procedure Governing Construction Work, Procurement and Disposal of Properties by Government Agencies (hereafter referred to as "the Inspection Ordinance," which was based on Article 59 of the Audit Act), and/or Guidelines for Invitations to Tender for Public Construction Works Drafted by the Executive Yuan (The Legislative Yuan of the Republic of China, 1994). Therefore, in Taiwan, the government developed public works in accordance with the Audit Act. The Inspection Ordinance, which contained only 24 regulations, was enacted in 1950 and abolished in 1999 after being in effect for 49 years.

The Inspection Ordinance was abolished in response to countries worldwide removing trade and tariff barriers in order to promote free trade, including the drafting of the 1947 Agreement on Government Tax and Trade (GATT); in 1995, the World Trade Organization (WTO) was established. To address the challenges of globalization, in 1990 Taiwan applied for participation in the GATT forum and became the 144th WTO member in 2002. Among the various WTO agreements, the current Agreement on Government Procurement, which was concluded in Uruguay in 1993, is most directly relevant to public works. When Taiwan applied for accession into the WTO, other countries requested that Taiwan first open its government-procurement market in order to conform to the Agreement on Government Procurement. Accordingly, the Government Procurement Act (GPA) was enacted in 1998 in accordance with the agreement and relevant regulations.

Here, the differences between the WTO-GPA and the Taiwan Government Procurement Act are outlined. The rules of transparency, equality and non-discrimination set by the GATT have already been complied with through the Taiwan Government Procurement Act. Differences between the WTO-GPA and Taiwan Government Procurement Act focus on three areas: Execution procedure, list of promised open-industries, and financing boundary. From 2015 to 2016, the WTO-GPA set the financing limit for procurement to $228,100,000NTD (Public Construction Commission, 2016a).

4. LEGISLATION PROCESS FOR PPP IN INFRASTRUCTURE PROJECTS

Enactment of the Act for the Promotion of Private Participation in Infrastructure Projects was preceded by the 1929 Privately Owned Public Utilities Supervisory Act and then the 1953 Statute of Privatization of Government-Owned Enterprises, which was not passed by the Legislative Yuan until 1991. In 1993, consensus was reached on a review report regarding a 6-year national development plan, and Taiwan began promoting private participation in infrastructure projects (Li, 2015). Subsequently, the Statute for Encouragement of Private Participation in Transportation Infrastructure Projects was enacted in 1994 (The Legislative Yuan of the Republic of China, 1994).

In 1995, the National Development Council in the Executive Yuan adopted a build-operate-transfer model in managing 22 projects aimed at promoting

national infrastructure development, including the north–south high-speed railway. In 1996, the National Development Council held a conference on national development, which culminated in the implementation of the Statute for Encouragement of Private Participation in Transportation Infrastructure Projects. The conference was aimed at modifying the range of legal applicability, as well as to form a legal basis for promoting private participation in infrastructure projects. Accordingly, the Act for Promotion of Private Participation in Infrastructure Projects was enacted in 2000 ((Division for Promotion of Private Participation, 2006b; The Legislative Yuan of the Republic of China, 1998). In addition, the Statute for Encouragement of Private Participation in Transportation Infrastructure Projects applied to investment contracts related to private participation until the statute was replaced with the Act for Promotion of Private Participation in Infrastructure Projects, which was deemed advantageous to private institutions. Subsequently, the statute was no longer valid under law.

5. ISSUES WITH THE GPA AND PPP IN INFRASTRUCTURE PROJECTS

5.1 The Constitution of Taiwan does not clearly distinguish the differences between service provision and gaining illegal profits, which leads to the possibility of law-abiding civil servants being subject to prosecution

In 2005, at the 995th ministry meeting, the Minister of Justice proposed relaxing the Act for the Promotion of Private Participation in Infrastructure Projects, and that concessions should be made to encourage private participation in infrastructure projects. This Act is a special law because it prevails over other related laws and is thus critical for law enforcement officers investigating cases relating to illegal profits. An offense involving illegal profit obtainment is judged on the basis of whether the involved persons have deliberately violated any law. “Deliberately violating a law” is a crucial element in a case for which the law related to inviting investors has been infringed upon. Regarding the procurement of evidence, according to Item 3 of Article 6 of the Government Procurement Act, the competent authority shall assist or provide counsel to the Judicial Yuan or Control Yuan when investigating, accusing, impeaching, or censuring procurement agencies or staff. If questions arise regarding whether cases are related to the Act for Promotion of Private Participation in Infrastructure Projects, the regulations in this Act stipulate when the competent authority shall assist or provide counsel to determine which Act shall prevail in order to prevent incidents of misjudgment.

5.2 Issues with how the government promotes private participation in infrastructure projects

5.2.1 Problems concerning the PPP system

Institute of Transportation (2009) examined cases in which the Act for the Promotion of Private Participation in Infrastructure Projects (referred to as

"the Act" in this section) has been enforced and identified the following issues:

(1) Real estate securitization: Public works cannot yield profits, which hinder business operations through public facilities; therefore, real-estate securitization and land trust cannot be implemented.

(2) Ambiguity between private and public investment contracts: The Act is unclear about whether investment contracts are considered private or public contracts.

(3) Entitlement premiums and rebates: To prevent conflicts of interest created by personnel involved in the Act, high entitlement premiums are offered; however, this hinders the number of services offered and improvements in service quality.

(4) Low awareness of how public works benefit the general public and the protection of disadvantaged groups: Discussions about public interest have been insufficient. For example, media coverage on subsidies for disadvantaged groups and environmental protection are not objective, which generate negative publicity about the Act.

(5) Need for an independent regulatory commission: In Taiwan, "a competent authority" is responsible for regulating utility rates, however, in other developed countries utility rates are regulated openly and fairly by an independent commission.

5.2.2 Factors contributing to conflicts of interests in the Act

Ministry of Finance (2015) reported 64.3% of the difficulties that government agencies have encountered related to the promotion of private participation in infrastructure projects were inexperience, poor advice, low professionalism among project executives and disputes with private enterprises who are eyeing up profits. Consequently, government agencies are hesitant about promoting private participation in infrastructure projects or are overly conservative when undertaking such projects.

In 2007, the Public Construction Commission of the Executive Yuan, an independent agency of the Executive Yuan, indicated that government agencies have encountered the following problems with the promotion of private participation in infrastructure projects: Unfamiliarity with the Act for Promotion of Private Participation in Infrastructure Projects; Government agencies mistakenly adopting the Government Procurement Act in cases where the Act for Promotion of Private Participation in Infrastructure Projects should be applied (and vice versa).

5.3 Most Government staff are unfamiliar with PPP Act

Government staff (accountants, auditors, accounting and statistics officers, ethics officials and prosecution and investigation officers) are unfamiliar with the Act for Promotion of Private Participation in Infrastructure Projects. Ministry of Finance (2014) hosted a forum to discuss issues about promoting private participation in infrastructure projects. The representative for the northern region of Taiwan argued that many civil servants lack experience and professional knowledge in promoting private participation in infrastructure projects, consequently, in the event of problems, the project manager is held accountable. In addition, civil servants are not encouraged to promote private participation in infrastructure projects and the Ministry of Finance lacks comprehensive guidelines, providing inadequate assistance to help project managers in solving problems. Furthermore, information presented at a seminar on political morality and government procurement erroneously

referred to cases related to the Act for Promotion of Private Participation in Infrastructure Projects as being related to the Government Procurement Act.[1] Similar problems have been encountered by both infrastructure project managers as well as staff in accounting, auditing, statistics, political morality, and prosecution divisions.

6. INTERNATIONAL TREND OF CIVIL PARTICIPATION IN PUBLIC WORKS

In order to utilize civil strength in public works, the British government began their promotion of private participation in infrastructure with the Channel Tunnel project between the UK and France in 1987. Based on different domestic environments, countries around the world have developed many mechanisms for private participation in infrastructure, such as: Build-Operate-Transfer (BOT), Build-Own-Operate (BOO), Build-Transfer-Operate (BTO), Private-Finance-Initiative (PFI), Build-Transfer-Lease (BTL), and Design-Build-Finance-Operate (DBFO). The summary is below (Elbing & Wettengel, 2011; Public Construction Commission, 2016b; Deautschland, 2008):

Table 1. Shows trend of PPP in the following countries

Nation	Law	Scope	Administration	Government Organization	Non-public Organization	Private company applying project by itself (Y/N)
Taiwan	Specific law, and gradually establishing working procedure and standard contract	Transportation facilities and common conduits; environmental pollution prevention facilities; sewerage, water supply and water conservancy facilities etc.	Administrative department is department of construction; central, county and city government	Executive Yuan Public Infrastructure Committee, Executive Yuan promoting civil participation in public infrastructure committee	No supporting organization; Events are advised by infrastructure; department on a case bases; Lacking the civil participation	**Y**
Japan	Specific law, and establish PFI basic guidance	Road, airport, sewer, public accommodation, social welfare and utility infrastructure.	Central government and regional government	PFI Promoting Office: Study the executive order PFI Promoting Office: Set out rules and guidance	PFI：Advertising, promoting, and supporting the audit from government. Project financing review: ：magazine PFI：Information integrating and open for	**Y**

[1] For example, when discussing government procurement ethics and transparency measures in a seminar about political morality and government procurement at the Taipei Veterans General Hospital, Gao-Yue Guan erroneously referred to cases related to promoting private participation in infrastructure projects as being related to government procurement. http://homepage.vghtpe.gov.tw/~ged/left1.htm

Nation	Law	Scope	Administration	Government Organization	Non-public Organization	Private company applying project by itself (Y/N)
					reviewing	
Canada	No specific law, establish several guidance	Any kind of public infrastructure, be used between the public sector and private sector as an alternative – more elastic	Federal government, provincial government, city government	P3s bidding need to be approved by Department of Finance	PBC help government department, CCPPP's education training program,research and publications	**N**
UK	No specific law, establish standard contract, specification guide and case study	Hospital, school, road, jail, national defense related construction, training center and building, etc.	Central and regional government	1.Department of finance: strategy manager 2.Congress National Audit Department and Public Account Committee: Central executive administrator 3.Local Audit Committee	1.Collaborating Corporation: Supported and developed by central government (public-private collaboration) 2.4Ps: Local promoting and training organization (half-public)	**Y**
Germany	No specific law, according to individual senate legislation	School, road, health care, energy supply, sewage disposal	Central and regional government	Ministry of Finance, Ministry of Transport, Ministry of Defense, Ministry of Economics	Public and private cooperation	**Y**

7. COMPARISON BETWEEN GPA AND PPP ACTS

This study compared the Government Procurement Act and the Act for Promotion of Private Participation in Infrastructure Projects for two reasons: to assist government agencies in determining whether they should adopt the Government Procurement Act (when budgeting for public works) or the Act for Promotion of Private Participation in Infrastructure Projects (when obtaining private funds), and to ensure that infrastructure developments satisfy public interest.

Table 2. Comparisons between the two Acts

Project	Comparisons between the two Acts
Laws related to government procurement	1.PPP: Cites the Statute for Encouragement of Private Participation in Transportation Infrastructure Projects; 2. GPA: Cites the Government Procurement Agreement and the Inspection Ordinance.
Drafting of legislation	1. PPP was introduced to broaden the scope of the Statute for Encouragement of Private Participation in Transportation Infrastructure Projects, to ensure that due diligence is exercised when promoting private participation in infrastructure

Project	Comparisons between the two Acts
	projects and to promote public interest; 2. GPA was enacted to establish an open, transparent, fair, competitive, efficient, trustworthy government procurement system in accordance with the Inspection Ordinance and WTO Agreement on Government Procurement.
Purpose of legislation	1. PPP was introduced to enhance the quality of public services, promote private participation in infrastructure projects and to stimulate economic development; 2. GPA was introduced to establish a fair procurement procedure.
Application of legal regulations	According to the Executive Yuan, government agencies shall promote private participation in infrastructure projects in accordance with the Act for Promotion of Private Participation in Infrastructure Projects.
Characteristics of legal regulations	1. PPP contains two chapters pertaining to promoting public interest (i.e., Land Acquisition and Development; Financing and Tax Benefits); 2. GPA contains two chapters pertaining to fraud prevention (i.e., Dispute Settlement, Protest, and Complaint; and Penal Provisions).
Implementation procedures	1. PPP: The government shall provide land and buildings; private investors shall provide funding; the procedure for land development or inviting investors shall be conducted openly and fairly, emphasizing the importance of cooperation; 2. GPA: The government shall provide funding and suppliers shall provide construction technology, labor and company property. Throughout the procurement, the government shall provide funding and maintain control of the procedure; private investors shall provide assistance if necessary.
Scope of application	PPP and GPA differ in their defined scope of application.
Relevant agencies	1. Cases in which PPP is applicable: The authority in charge, authorized institutions and commissioned agencies; 2. Cases in which GPA is applicable: Government agencies, public schools, government-owned enterprises, entrusted corporations or groups, and other agencies of professional capacity.
Private participation in infrastructure projects	1. PPP contains two procedures pertaining to announcements made by the government and planning undertaken by private institutions; 2. GPA states that the government shall control the implementation procedure; suppliers cannot plan their level of participation. In addition, the Act for Promotion of Private Participation in Infrastructure Projects applies to cases involving private participation in public construction.
Public procedure for inviting public participation	1. PPP: The government shall invite investors and cooperate with private institutions openly and transparently; 2. GPA: Regarding a fair procurement procedure, the government shall announce information on invitations to tender in the Government Procurement Gazette and online. Thus, the Act for Promotion of Private Participation in Infrastructure Projects is more open and transparent compared with the Government Procurement Act.
Confidentiality provisions	1. PPP: Except for the negotiation process and review content, other procedures related to inviting investors shall be conducted openly and transparently; 2. GPA: Tender documentation shall remain confidential before the documents are published; the reserve price as well as the list and number of suppliers that have submitted tenders shall not be revealed before the opening of tenders.
Negotiation mechanisms	1.PPP: Documents related to inviting investors state that negotiations may be undertaken to facilitate selecting the best applicant; 2. GPA: When the awarding of a contract cannot be decided, the contract may be awarded through negotiations, but only after the entity has received approval from the superior entity and after announcing such intentions in the tender documentation.
Selection and review procedures	1. Selection Committee members: In accordance with PPP, the list of Selection Committee members may be announced in tender documentation provided that all Selection Committee members agree unanimously; in accordance with the Government Procurement Act, the list of Procurement Evaluation Committee members shall remain confidential; 2. Chairperson: In accordance with the Act for Promotion of Private Participation in Infrastructure Projects, the chairperson of the Selection Committee shall be elected by the Selection Committee; in accordance with the Government Procurement Act, the chairperson shall be a senior member of the agencies.
Bid selection and	1. PPP: Negotiation and execution of concession agreements;

Project	Comparisons between the two Acts
contract signing procedure	2. GPA: Negotiation and comparison of procurement tenders followed by the execution of concession agreements.
Bid bond and security deposit	1. PPP: No regulations are stipulated regarding the confiscation of the security deposit in order to encourage cooperation between the government and private institutions; 2. GPA: The bid bond is not returned and security deposit is confiscated.
Nature of contract	1. PPP: Civil law may be applied if no contractual laws govern the investment contracts. This Act removes the power possessed by the government for administrative contracts and promotes cooperation between the government and private institutions on the basis of equality; 2. GPA: The government determines how to formulate procurement contracts.

Table 3. Rules for promoting public interest and preventing fraud

PPP	GPA
Measures for promoting public interest	Measures for preventing fraud
(1) Relaxation of legal limitations 1. No regulatory restriction on foreign investment; 2. Relaxation of the business term for private institutions; 3. Relaxation of contract term for lease contracts; 4. Relaxation of rules regarding leases, superficies, trusts, premiums, or rents; 5. Sale of sporadic public lands; 6. Land expropriation (a) Limitation of control over price negotiations; (b) Land expropriation plan may stipulate the terms of land development, business cooperation, land lease, creation of superficies, trusts, or land premium, and rent contribution; (c) The use of expropriated lands for infrastructure projects by private organizations is not limited by Article 25 of the Land Act, Article 28 of the National Property Act, or legal regulations stipulated by local government agencies responsible for managing public land; (d) Leasing expropriated lands and creating superficies; 7. Development of public lands; 8. Infrastructure passing above, under, or through public or private land; 9. Expropriation of part of private land for infrastructure projects; 10. Announcements restricting construction and advertisements. **(2) Financing and tax benefits** Chapter 3 of the Act for Promotion of Private Participation in Infrastructure Projects: 1. Subsidies: the authority in charge may, on the part of the inadequate self-financing portion, subsidize part of the interest accrued from the loan needed by the private institution or, invest in part of the construction; 2. Long-term loads; 3. Relaxation of credit limits; 4. Foreign financial institutions jointly	**(1) General rules** 1. Procurement rules: (a) Private organizations shall be treated equally; (b) Procurement staff shall not infringe this Act; (c) Judicial, control, or other government agencies may request assistance or counsel from the authority in charge when investigating, prosecuting, judging, impeaching, or censuring procurement agencies or staff; 2. Supervision by the superior entity; 3. Operations in procurement agencies; 4. Limitations of procurement operations; 5. The principle of avoiding conflicts of interest shall be followed; 6. Managing conflicts of interest. **(2) Invitation to tender** 1. Open tendering procedures; 2. Suppliers are given equal opportunity to be invited; 3. Principle of joint bidding; 4. Technical specifications may not be limited; 5. Announcement of invitations to tender; 6. Waiting time for tendering; 7. Bid bond and security deposit; 8. Confidentiality principle; 9. Qualifications of suppliers may not be used as reason of rejection without adequate explanation; 10. Political parties and their affiliated enterprises may not submit tenders; 11. Suppliers with political affiliations may not submit a tender. **(3) Awarding of contracts** 1. Tenders shall not be opened until the bid is awarded; 2. No opening or submission of tenders for private organizations; 3. Announcements of the awarding of contracts; 4. Tenders are information about the

PPP	GPA
provide loans to private organizations; 5. Publicly issuing new stocks; 6. Issuing purpose-designated corporate bonds ; 7. Tax relief: business income tax, tariffs, land tax, property tax, and deed tax; 8. Investment tax credits. **(3) Rent concessions** 1. Public land: According to Items 1 and 2 of Article 15 of the Act for Promotion of Private Participation in Infrastructure Projects, after using public lands, the authority in charge may lease the land and provide rent concessions; 2. According to Item 1 of Article 18 of the Act for Promotion of Private Participation in Infrastructure Projects, when the space above or under public or private land is leased to private institutions. **(4) Administrative rules** 1. Rules pertaining to rent concessions for leasing public land and creating superficies are aimed at promoting private participation in infrastructure projects; 2. Award rules for encouraging agencies to promote private participation in infrastructure projects; 3. Rules for awarding the golden prize for construction to encourage private participation in infrastructure projects;	awarding of contracts. **(4) Compliance management** 1. Essential elements of contracts; 2. Guidelines on violations of subcontracting restrictions; 3. Suppliers are accountable for defective works; 4. Construction quality control measures; 5. Rules for construction inspection panels. **(5) Penal provisions** 1. Penalties related to suppliers operating on self-interest; 2. Penalties related to procurement staff who reveal confidential documents; 2. Penalties related to procurement decisions that deviate from the original plan; 3. Penalties related to forcing procurement staff to reveal confidential documents; **(6) Additional rules** 1. Competent authorities may investigate progress; 2. Suppliers shall be notified about how they have violated a law and the infringement shall be announced in the government gazette;
PPP	GPA
Measures for preventing fraud	Measures for promoting public interest
(1) Supervision and management; (2) Selection Committee members may not be influenced illegally or recommend themselves as committee members; (3) Selection Committee members shall remain impartial throughout the selection procedure. For example, they may not receive bribes, kickbacks, gifts or concessions; (4) Selection Committee members shall avoid conflicts of interest.	(1) According to Article 44 of the Government Procurement Act, because of price difference, Taiwanese suppliers are given preference in being awarded a contract. (2) Priority on the procurement of green products. (3) Government agencies shall help small and medium-sized enterprises to implement a government procurement contract or subcontract.
Comparisons between the two Acts	1. PPP: Positively framed regulations for promoting public interest; 2. GPA: Negatively framed regulations for preventing fraud.

8. CONCLUSION

(1) In this study, the Act for Promotion of Private Participation in Infrastructure Projects and the Government Procurement Act were reviewed and compared because the historical background, legislative purpose, implementation procedures, transparency and confidentiality regulations are fundamentally different between the two Acts. Executives should avoid erroneously misapplying laws.

(2) The Government Procurement Act contains more regulations related to preventing fraud compared with the Act for Promotion of Private Participation in Infrastructure Projects. The rules on confidentiality are as

follows: the content of tender documentation and the reserve prices shall remain confidential until the winning applicant is announced. Through the principle of confidentiality and a fair procurement mechanism, the quality of procured products can be assured. The Act for Promotion of Private Participation in Infrastructure Projects covers more concession regulations than does the Government Procurement Act. Providing an open and transparent mechanism facilitates the acquisition of private investors. Through implementing such a mechanism, government agencies can improve investor confidence.

9. RECOMMENDATIONS

Currently, regarding implementing the Act for Promotion of Private Participation in Infrastructure Projects, the differences between service provision and gaining illegal profits cannot be distinguished; therefore, civil servants are reluctant to take on additional responsibility in fear of being held accountable. Based on the findings of this study, the following recommendations are proposed to provide a reference for government agencies to promote private participation in infrastructure projects:

(1) Because of the zero premium and rebates, public construction does not benefit public interest. In an investment contract, unusually high operating profits should be reported and premiums and rebates should be increased.

(2) The amount of funding that private institutions can acquire from banks should be limited in order to reduce the level of risk exerted on the government when private institutions fail to operate as contracted.

(3) The Act for Promotion of Private Participation in Infrastructure Projects should be clearly defined to facilitate mutual trust and cooperation between the government and suppliers in order to promote private participation in infrastructure projects.

(4) Executives at government agencies should receive adequate training to ensure that they possess the required professional skills and knowledge to facilitate the establishment of specialized consultancies.

(5) Government employees, including judicial officials, accounting and statistics officers, auditors, investigators and ethics officials, should be invited to seminars to achieve consensus about the Act for Promotion of Private Participation in Infrastructure Projects and raise awareness of the Act for Promotion of Private Participation in Infrastructure Projects and the Government Procurement Act.

(6) The Act for Promotion of Private Participation in Infrastructure Projects should be amended to include regulations requiring government agencies to seek counsel or counsel from competent agencies when investigating, prosecuting, judging, impeaching and censuring agencies or people who are responsible for promoting private participation in infrastructure projects.

(7) Because prosecutors and judges are subject to human error, a professional advisory committee, specialized court or jury system should be established to handle cases related to promoting private participation in infrastructure projects in order to prevent judges with inadequate knowledge, job experience or empathy from making misjudgments, which can make civil servants become conservative in developing national infrastructure and utilizing public assets.

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