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Framework for Evaluating Sustainability of Transport System in Megalopolis and its Application

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Abstract

It has been acknowledged that megalopolises are playing a leading role in the processes of both economic development and culture change. Thereupon, the new emphases on sustainability of transportation system in megalopolis are creating new demands for adequate approach to measure its performance and diagnosis potential drawbacks. By examining the descriptions of sustainable transport system as well as its evaluating approach, a framework with the general applicability and easily accessible data resource for evaluating sustainability of transport system in megalopolis is developed based on nature of regional structure and the feature transport demand in megalopolis. The proposed framework is applied in the analysis and comparison of Jing-Jin-Ji and Yangtze River Delta..

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Keywords: Megalopolis; Transport system; Sustainability; Framework; Jing-Jin-Ji; Yangtze River Delta

1. Introduction

Sustainability is an increasingly important issue of transportation system in populous areas, and congested traffic conditions, declining air quality and the demands for improved access to livable transport service are

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common in more and more areas around the world[1]. A growing amount of researchers and practitioners are concerning about the sustainability of urban transportation system. But few people have paid close attention to transportation system sustainability in megalopolis. It should not be neglected that megalopolis has been regarded as the main settlement pattern[2] and crucial economic geography phenomenon[3], and megalopolises are here to stay for the foreseeable future[4]. In the on-going globalization of economic, social and cultural processes, megalopolises play the role of nodal points where human activities concentrate[5].

Compared with other congeneric reaches, this paper is more that of developing framework for evaluating sustainability of transport system and the presenting its application on the comparing the two megalopolises Jing-Jin-Ji and Yangtze River Delta. The most advantage of the framework is that it is firmly rooted in the regional nature of megalopolis and features of transportation demand in megalopolis and its data sources based on the regular statistics can be reached at very low cost. And the application verified the feasibility and the usefulness of the elaborate indicators.

2. Development of evaluating framework

The objective of this chapter is to analyse structure and content of evaluating framework with which the sustainability of transportation system in megalopolis can be quantitatively measured. And the evaluating framework is supposed to be endowed with the following attributes: a) systematic set of measurable indicators which firmly rooted in the nature of sustainability and that of transportation system in megalopolis; b) and data sources which are detailed enough to carry out the analysis and can be found in other megalopolis to establish comparisons.

The fundamental role of transport system is to facilitate mobility. But too much attention and effort have been paid on enhancing operating speed. A perspective of sustainability has shifted the emphasis from seeking higher operating speed to seeking more comprehensive goals across economic, social and environmental dimensions[6]. Now several frameworks or indicator system can be found in existing literatures for measuring sustainability in transportation system or in a certain regional level, but no standard one exists and unlikely appears due to the disagreement on the definition of sustainability and the various purposes of establishing a framework. The frameworks found in the literatures can be placed into three categories: 1) linkages-based frameworks, 2) impacts-based frameworks and 3) influence-oriented frameworks[7]. According to this classification, the framework proposed in this paper belongs to the second type which focus on the nature and extent of various kinds of impacts (e.g., economic, environmental, social) that collectively determine the sustainability of a system.

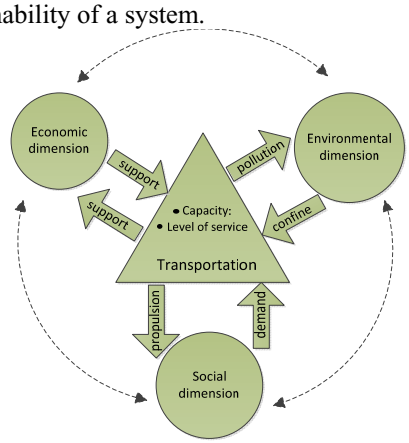

Fig. 1 the interrelation among transportation and the three dimensions of sustainability

Economic, environmental and social dimensions are regarded as the triple-bottom-line principle of sustainability, and the interrelation among transportation and the three dimensions can be interpreted as what are shown in Fig.1. The basic nature of transportation is to fulfill the mobility of passengers and goods, and the first primary factor of transportation is its capacity. Transport capacity firstly manifests as the amount of vehicles, the length of transport lines and so on. The second primary factor is service quality like connectivity, accessibility, as well as fare. The interdependence between transportation and economic state is undeniable and requires no more explanation. With the ever-increasing traffic volume, the negative impacts of transportation on environment loom larger and larger in nowadays and environment in its turn is restricting the development of transportation in available land and energy. However, transportation sector is facing with more and more intractable demand from the society, while various efforts have been undertaken to improve the harmony between transportation and social dimension.

Based on the above illumination, we propose a framework as follows.

1) Environmental dimension

In the indicators proposed by [9], the three indicators arable land, CO_2 emissions, and commercial energy use are adopted to reflect the environmental dimension of sustainable transport. But EEA [10] has pointed out that Nitrogen Oxides are the major air polluting problem and is much more harmful that CO_2, so we adopted Nitrogen Oxides emission instead of CO_2 emission to depict the impact of trans port on air quality. Transport noise is an increasing issue affecting more and more urban inhabitants. Prolonged noise exposure can impact on amenity values and health in some circumstances; therefore it is necessary to take the indicator of transport noise into the consideration.

2) Social dimension

A sustainable transport system should be in favor of fostering health and well-being in the community at present and in the future. However social concerns are more abstract then other aspects so that it is more difficult to measure the social performance of transport system. Hereby to capture the critical issues of social dimension, safety & security and adaption are chosen as the social factors. And we suggest using traffic accident amount along with traffic accident loss to denote the frequency and severity, and using the ratio of motor car to population to denote the social adaption of transport system.

3) Economic dimension

Though there are plenty of economic indicators of relating to the sustainability of transport sector, two categories can be roughly seen, individual ones and the communal ones. For individual economic aspect, the percentage of traffic expenditure to total expenditure in daily life is quite visualized and easily measured by statistical data. For communal one, the input and output value are the fundamental factors and also easily to be measured in an utter objective way.

4) Mobility

A lot of mobility indicators systems have been proposed by European and other international institutions by adopting a multidimensional approach that takes into account multiple impacts of transport activities[8], for instance, PROPOLIS. To capture the essential of mobility and avoid unnecessary overlap with other dimensions, the two factors of connectivity and coverage rate are selected. Lengths of railways and highways are used to represent the former one and the transport network density (the ratio of total length of railway and highways weighted by their average transport capacity to the area of studied region) is used to represent the latter one. The coverage rate is computed by Eq.(1)

$$c = T \,/\, L \tag{1}$$

where c is the coverage rate, T the total converted turnover in ton-kilometer, and L the total mileage in service. The data of T and L can be found easily in the yearly statistical bulletin of the Ministry of Transport.

Besides, passenger turnover in unit area is adopted to denote the congestion degree.

The sustainability of transportation covers several different aspects of value judgments relating to transportation technology, sociology, economy, and environment protect. Therefore, it is very impossible to get any straightforward solution but a compromise one. Performance evaluation of transport system requires an adequate evaluation methodology that can provides a comprehensive benchmark. Multicriteria evaluation is particularly well suited for this purpose, for it allows for a flexible way to deal with multidimensional factors so that can be used to dissect a single dimension as well as a holistic system. Multicriteria evaluation have been effectively applied to the relative studies[11, 12]. A detailed discussion of the process of multicriteria evaluation is beyond the confine this paper. Readers are instead referred to the monograph [13].

Table 1 Description of the indicators

Goals	Factors	Indicators
Mobility	• Connectivity • Coverage rate • Transport capacity • Congestion	• Length of railways in operation[f,+] • Length of highways[f,+] • The density of transport network[f,+] • Total turnover of passenger traffic[f,+] • Ratio of turnover of passenger to area[f,-]
Environmental Dimension	• Energy consumption • Pollution • Land use • Noise	• Final petroleum products consumption of transport, storage and post industry[f,-] • Nitrogen oxides emission of motor vehicle[b,-] • Percentage of land for transportation facilities[b,-] • Percentage of roads with excess noise[b,-]
Social Dimension	• Safety & security • Adaptation	• Amount of traffic accident[f,-] • Total loss of traffic accidents[f,-] • motor vehicles for public transport per 10000 population, standard unit[b,+]
Economic Dimension	• Expenditures of the patronage involved • Investment and operating costs • economic benefit	• Ratio of expenditure on traffic to the total cash consumption expenditure for average individual[c,-] • Amount of standard operating motor vehicles[b, f,+] • Investment in fixed assets of transport, storage and post industry[f,] • output value of Transport, storage, and post industry[f,+]

Notes: a. China Energy Statistical Yearbook; b. China Statistical Yearbook on Environment; c. China Statistical Yearbook for Regional Economy; d. Yearbook of China Transportation & Communications; e. China Social Statistical Yearbook; f. the yearbook of the administrative region involved, like Beijing Statistical Yearbook, Tianjin Statistical Yearbook, Hebei Economic Yearbook, etc.; the signs of '+'and '-' are desirable change signs.

3. Basic information of Jing-Jin-Ji and Yangtze River Delta megalopolises

Today Jing-Jin-Ji, Yangtze River Delta, and Pearl River Delta, have been regarded as the top developed megalopolises in china[14]. Jing-Jin-Ji megalopolis, including Beijing, Tianjin, and eight cities in Hebei province, is acting as the political and cultural center of China, and the primary industrial core of northern China.[15]. Yangtze River Delta megalopolis, centralized by Shanghai and composed of 13 cities in Jiangsu province, 11 cities in Zhejiang province and 5 cities in Anhui province, is the most prosperous and urbanized region in China. Its economic aggregate is more and more exceeding that of Jing-Jin-Ji and Jing-Jin-Ji is the worst one of the three according to a study of comprehensive development environment. Since sustainable transportation is the cornerstone of development, we will apply the indicators and framework proposed hereby to dissect the gap of sustainability in the transport systems in the two regions aiming to facilitate finding the way of catching up for the laggard.

To give intuitive comparisons for the indicators with different units, all the data of various indicators have been processed by the standardization that all the data of Jing-Jin-Ji megalopolis are converted into 1 and the

corresponding data of Yangtze River Delta are converted into a percentage, so that different indicators of one goal are contrasted in the same chart.

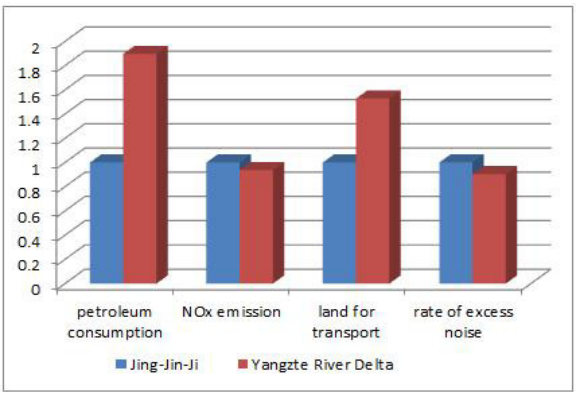

Fig. 2 Comparison of environmental factors

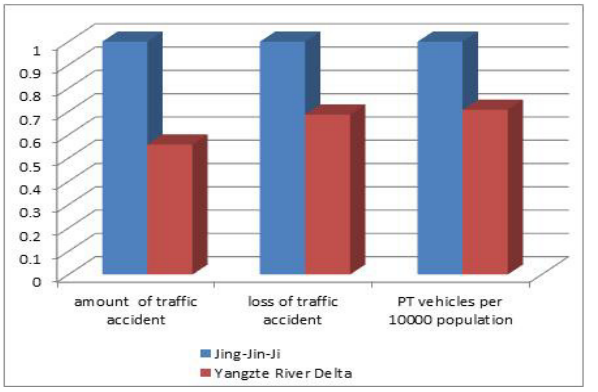

Fig.3 Comparison of social factors

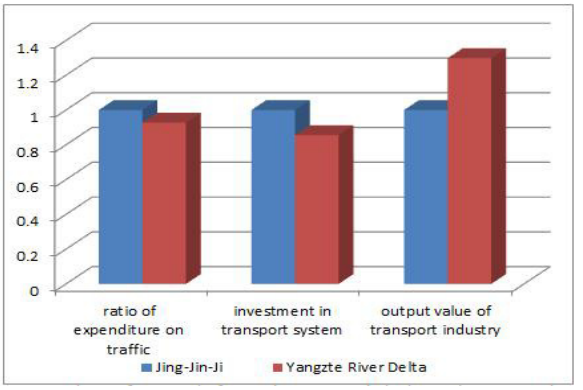

Fig.4 Comparison of economic factors

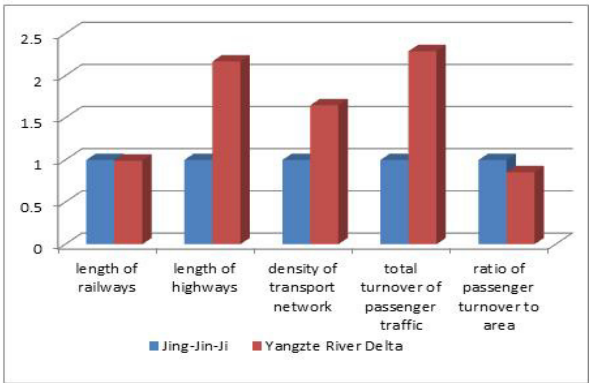

Fig.5 Comparison of mobility factors

4. Comparison and analysis on Jing-Jin-Ji and Yangtze River Delta

As is shown in Fig.2, the petroleum consumption in Jing-Jin-Ji is less than 0.55% of that in Yangtze River Delta, and the land use for transportation in Jing-Jin-Ji is 67% of that in Yangtze River Delta, which suggests that Jing-Jin-Ji is practising much more efficient resource utilization in transportation while the public transportation service volume is 1.5 times greater than that in Yangtze River Delta (See the Fig.3). But So far neither air pollution state nor noise pollution state in Jing-Jin-Ji can engender optimism due to the superabundant total amount of motor vehicles.

Traffic accident abatement is an endless plea for transportation sector. In contrast with Yangtze River Delta, Jing-Jin-Ji is apparently operating transportation system with more safety hazard. The amount and loss of traffic accident in Jing-Jin-Ji have been up to about 1.8 times and 1.45 times of those in Yangtze River Delta respectively (as shown in Fig.3). Safety and security is a vital aspect in the process of constructing

sustainable transportation system in any regional scale and the striking contrasting result should rouse effective rectification.

Economic growth requires a quick and efficient transport system, at the same time transport activity is also good part of economic sector. The inhabitants in Jing-Jin-Ji pay a little more fraction of the total expenditure than those in Yangtze River Delta, but the transportation system in Jing-Jin-Ji produces less 77% than that in Yangtze River Delta. In other words, the people in Jing-Jin-Ji benefit from the immense financial investment and subsidy, which is manifested by the second set of bars in Fig.3.

The essential nature of transportation is acting as a provider of mobility service. In term of transport capacity, the total turnover of passenger traffic in Jing-Jin-Ji is only 60% of that in Yangtze River Delta (as shown in Fig.4) and the immediate cause is the comparative lack of highways which lead to a rather less dense transportation network. Consequently, people in Jing-Jin-Ji are suffering more serious congestion in a little higher possibility.

5. Summary and conclusions

From the preceding sector, the following conclusions can be reached:

Firstly, comparing with Yangtze River Delta, Jing-Jin-Ji demonstrates its superiority in resource conversation which mainly benefits form the huge pubic rail transit system, but a large number of the private cars cause the undesirable environment characterized by the excessive air pollution and noise. All this is urging to optimize the structure of transport system in the megalopolis by means of limiting the ownership of private car and encouraging green car.

Secondly, the shocking traffic accident figures of both Jing-Jin-Ji and Yangtze River Delta are against their social effects. On the end of transport sector, especially for that of Jing-Jing-Ji, the matter of great account is to intensify the traffic management system and to improve the relating technical measures. A smooth multilateral coordination base on advanced information technology is an imperative to build more powerful system of accident prevention and major accident rescue system.

Thirdly, the transport system in Jing-Jin-Ji rides on the immense financial support from the government, and the inferior economic effect is calling for more various ways of fund-raising to realize a rational and long-lasting economic circumstance. Now there are some optimistic signs such as the market-based financing and fare adjustment of urban rail transit.

The last but not the least, the fact that the total amount of transport service is insufficient is confirmed by the above quantitative analysis results of less transport network density and worse state of congestion, therefor, higher coverage rate of transport network and improve public transport service are in need for the areas around Beijing, like majority areas of Hebei province. Above all, any single large city is not powerful enough to build a prosperous megalopolis, but only dynamic equilibrium within different parts of the megalopolis will lead to integrating development of the megalopolis.

The application on Jing-Jin-Ji and Yangtze River Delta have shown that the framework is fit to capture the particular qualities of megalopolis and then to analysis and compare kindred megalopolises with readily accessible data source. After all for a megalopolis, the main difference from a large city is the administration partitioning between different provinces and the barrier between urban area and suburb area. The framework provides a way to come across the obstacles to dissect several megalopolises under the universal benchmark, so that facilitate exploring the root cause of something unpleasant and devise adequate countermeasures. To avoid the influence of natural conditions, those factors relating to water transport haven’t been taken into consideration. Due to limited space, the integrated analysis using multicriteria evaluation cannot be presented.

The main limitation of this framework is the lack of indicators of social equity brought by transport system. Equity is one of the most important factors but it is the most difficult one to be quantified and addressed. Although we have treated equity as an integrated part of principle of sustainability and represented it in other indicators, like density of network, and ratio of traffic expenditure, elaborate approach of measuring the equity is a very intriguing project in the future research.

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