Evaluating urban transportation quality: measuring transportation activity

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Abstract

When people think about transportation improvements they often envision new modes of travel: canals, steamships, railroads, automobiles and air travel. What comes next? Rockets? Lighter-than-air ships? Teleporters? Perhaps these may become more common in the future. But they will not necessarily solve existing transportation problems such as urban traffic congestion, parking costs or traffic crashes. The next major breakthrough to improve transport system quality may simply consist of management strategies that result in more efficient use of existing transport resources. When all impacts are considered, such strategies are often the best solution to transportation problems. This paper first studies the definition and connotation of transportation efficiency and quality. From the viewpoint of different groups participating in urban transportation systems, different system functions and targets required by each group are analysed. Then the corresponding system targets and evaluation rules required by the administrator are studied. Finally we discuss different methods used to measure urban transportation, the different perspectives they represent, and how the selection of one or another method tends to affect transportation and land use planning decisions.
Keywords: urban transportation efficiency, urban transportation quality, urban transportation system, and performance evaluation.

1 Definitions

1.1 General considerations of urban transportation

With the spread of industrialism and the growing size of cities, it is no longer possible for many city dwellers to live within walking distance of work. Urban transportation has become increasingly important as our cities continue to grow.

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1.2 What is transportation demand management?

Transportation Demand Management or TDM (also called Mobility Management) refers to various strategies that change travel behaviour (how, when and where people travel) in order to increase transport system efficiency and achieve specific objectives such as reduced traffic congestion, road and parking cost savings, increased safety, improved mobility for non-drivers, energy conservation and pollution emission reductions. There are many different TDM strategies with a variety of impacts. Some improve the transportation options available to consumers, while others provide an incentive to change travel mode, time or destination. Some reduce the need for physical travel through mobility substitutes or more efficient land use. Transportation Demand Management is an increasingly common response to transport problems.

1.3 Why manage transportation demand?

There are many reasons to manage transportation demand, as summarized below. A common mistake people make is to assume that there is only one solution to a particular problem. Put another way, often the best solution to a problem is not the one that first comes to mind – finding the best solution may require looking at the problem in a new way, and research to find innovative approaches.

In the past, transportation problems were usually evaluated in terms of supply: building more road, parking and airport capacity. Increasingly, management solutions are being used that result in more efficient use of existing capacity. There are many reasons to consider using these solutions. Some of these reasons are described below. Transportation Demand Management can provide multiple benefits including congestion reduction, road and parking facility cost savings, consumer savings, improved transportation choice, road safety, environmental quality, community liveability, efficient land use, and equity. As a result, total benefits are often much greater than other solutions that only address one or two problems. When all benefits and costs are considered, Transportation Demand Management is often the most cost effective solution to transportation problems. TDM can provide significant savings by reducing and deferring the need to increase road and parking capacity, reducing vehicle operating costs, and reducing crashes and pollution emissions. TDM provides a flexible response to many types of transportation problems, including those that are urgent, temporary, variable or unpredictable. TDM programs can often be implemented quickly, and can be tailored to a particular situation and user group. Demand management avoids the risk that a major capital investment will prove wasteful due to unforeseen changes in transportation needs. TDM can provide direct and indirect consumers benefits. Many TDM strategies use positive incentives. They improve transportation options and provide new financial savings or other benefits to reduce vehicle use. In addition, TDM can be a cost effective way to reduce traffic congestion, parking problems, crash risk and pollution emissions, all of which benefits consumers. TDM can help achieve equity objectives. It can result in a fairer allocation of resources between different demographic and geographic groups. Many strategies directly benefit people who are economically, physically or socially disadvantaged by improving transportation options available to non-drivers.

1.4 Definition of transportation efficiency

The basic definition of efficiency is the relationship between input and output, or between costs and benefits in a certain system. In economics, the general meaning of efficiency is the extent to which a certain amount of productive resources can meet the demand of human beings [1]. The relationship between efficiency, input and output in a system can be explained by the following equation:

$$O = I - E \tag{1}$$

where: O = the capacity of satisfying certain demands, or the output of a certain input; I = the quantity of productive resources input in the system; E = the efficiency of the system. From equation (1), it can be noticed that efficiency is the key parameter that determines the total supply of a system. Given the same amount of input, different efficiency will conduce to quite different output.

The relationship between demand and supply in a transportation system, which is an important component of the national economy, also satisfies equation (1).

In this paper, transportation efficiency is defined as: the extent to which certain transportation input can meet the travel demand of people in a transportation system. It is the main factor that determines the scale of transportation supply and the relationship between supply and demand in a transportation system. In a macroscopic point of view, if we take transportation infrastructure as the input element and take transportation mobility (or transportation capacity) as the output element in transportation systems, then transportation efficiency is the macro parameter influencing the input/output proportion of the system.

1.5 Category of transportation efficiency

The transportation system is a complicated, open and boundless system. Therefore the meaning of transportation efficiency is not unique. Different groups of interests, different system objectives and research perspectives, will all lead to different comprehensions and values to transportation efficiency. Generally, transportation efficiency can be further categorized as macrocosmic or microcosmic, intercity or intracity, passenger or freight transportation efficiency, etc. At the same time, different categories are interrelated. If combined by certain means, more particular categories can be obtained, for example: efficiency of urban passenger transportation system, efficiency of intracity freight transportation system etc. The efficiency of urban transportation systems is the relationship between the input of an urban transportation system and its capability of satisfying the transportation demand in the system. Generally, the total efficiency of the urban transportation system is scaled by "social benefits/social costs".

1.6 Performance evaluation

Performance Evaluation refers to monitoring and analysis of policies, programs and projects as they are implemented in order to determine how well they are performing with regard to their intended objectives. This can help determine whether a planning decision was appropriate, identify potential problems, and to provide guidance for optimization. This tends to be particularly important for innovative solutions, such as TDM (Transportation Demand Management).

1.7 Mobility

Mobility refers to the movement of people or goods. It assumes that “travel” means person or freight travel and “trip” means person or freight-vehicle trip. It assumes that longer trips provide greater value to society than shorter trips, and faster modes are superior to slower modes. It supports an integrated view of the transportation system, with attention to connections between different modes. For example, it recognizes that most transit trips involve at least one walking link, and so walking and transit are complementary travel modes.

1.7.1 Users

From this perspective, transport users are mainly motorists, since motor vehicles provide the majority of personal-miles and freight transport, but on some corridors there are enough transit users, rideshare passengers and cyclists to justify special consideration. It recognizes that a significant minority of residents use non-automobile modes at least occasionally.

1.7.2 Modes

This perspective considers motor vehicles as most important, but also values transit and ridesharing on congested corridors, and recognizes that walking and cycling may be important in areas such as college towns and resort communities. It supports an integrated view of transportation systems, with attention to connections between modes. It justifies devoting a modest portion of transport funding to transit, HOV and cycling.

1.7.3 Land use

From this perspective, convenient highway access and parking is considered most important, but transit and HOV access are also desirable in areas where density and demographics concentrate enough riders. The best location for major activity centers is where there is a combination of convenient roadway access, adequate parking, and transit service, and a central business district can be accommodated by emphasizing transit.

1.7.4 Transport problems and solutions

A mobility perspective favours solutions that increase transport system capacity and speed, including highway improvements, transit improvements, ridesharing, intermodal passenger and shipping facilities, high-speed train and aviation. It tends to give little consideration to walking and cycling except where they provide access to motorized modes, since they represent a small portion of person-miles. From this perspective, the best way to address the barriers facing non-drivers is to improve mobility options, including automobile, taxi, transit and no motorized transport modes.

2 Performance measurement system

Performance indicators (also called measures of effectiveness) are practical ways to measure progress toward established objectives. Various performance indicators can be used to evaluate transportation system quality and the effectiveness of a TDM program. These usually include both quantitative measures of mobility and access, and qualitative measures of user acceptance and satisfaction. In most cases, no single indicator is adequate, so a set of indicators that reflect various objectives and perspectives are used. Which indicators are selected and how they are weighted and presented implicitly defines the value placed on different objectives.

2.1 Conventional performance indicators

Conventional transport indicators mostly consider motor vehicles traffic conditions. Below are examples: roadway level-of-service (LOS), which is an indicator of vehicle traffic speeds and congestion delay at a particular stretch of roadway or intersection. A higher rating is considered better; average traffic speeds, assumes higher is better; average congestion delay, measured annually per capita. Lower is considered better; parking convenience and price. Increased convenience and lower price is considered better; crash rates per vehicle-mile. Lower crash rates are considered better; because they only consider motor vehicle travel conditions, evaluating a transportation system based on these factors tends to favour automobile-oriented improvements over other objectives and solutions. For example, they justify road and parking facility capacity expansion that tends to create more automobile-oriented transport and land use systems, increasing per capita vehicle travel and reducing the viability of walking, cycling and public transit. This increases per capita vehicle ownership and use, increasing resource consumption, pollution emissions and land consumption, and exacerbating the transport problems facing non-drivers.

2.2 Comprehensive performance indicators

A more comprehensive set of performance indicators that take into account a wider range of travel modes and impacts can be used to evaluate transportation system quality. These can be selected and modified as needed to reflect the values, needs and conditions of a particular planning situation. Below are examples. *Commute accessibility*: Average commute travel time. Lower is better. *Land use mix* - Number of job opportunities and commercial services within 30-minute travel distance of residents. Higher is better. *Land use accessibility*: Average number of basic services (schools, shops and government offices) within walking distance of residences. Higher is better. *Children's accessibility*:

Portion of children who can walk or bicycle to schools, shops and parks from their homes. Higher is better. *Electronic accessibility*: Portion of population with Internet service. Higher is better. *Transport diversity*: Variety and quality of transport options available in a community. Higher is better. *Mode split*: Portion of travel made by walking, cycling, rideshare, public transit and telework. Higher is better.

3 The evaluation objective of urban transportation efficiency

3.1 Basic evaluation objectives and principles

The evaluation of any system is based on certain objectives. The development objective of urban transportation systems held by humans has varied with the progress of their notions of city and development. The developing target of a sustainable urban transportation system can be divided into three groups, which are the target of transportation functions, the target of resources utilization and the target of environment protection. The target of transportation functions means to satisfy the normal transportation demand brought by the development of economy and the living of citizens. It is the most elementary target an urban transportation will have, and includes accessibility, swiftness, security and comfort. The environment protection target requires that the urban transportation behaviours should reduce as much as possible their negative effects on the environment and ecosystem.

The resources utilization target requires the urban transportation system to effectively utilize the land, energy, and human resources.

Based on the definition of urban transportation efficiency, whether an urban transportation system can be evaluated as “efficient”, is determined by whether the system can realize most of its developing targets with the lowest transportation inputs [2]. Corresponding to different developing targets, there are different principles for evaluating the urban transportation efficiency, which can be expressed in figure 1.

3.2 Category of evaluators

Any evaluation procedure must be carried through from the viewpoint of a certain evaluator and should take the ideal anticipation of the evaluator as its reference. As a highly opened public system, the urban transportation system has three groups of participants: the planner and administrator, the operator, and the user of the urban transportation system. Different groups of participants have different anticipations of the urban transportation system, correspondingly, the comprehensions and evaluation focus on urban transportation efficiency held by each group is different. Generally, the planners and administrators of urban transportation are in the view of the whole urban transportation system. They hope that the citizen transportation demand, which derives from the producing and living activities, can be mostly satisfied, and that the occupation of resources and impacts on the environment can be diminished as much as possible. At the same time, they anticipate that the urban transportation can positively feed back and promote the economic development and land-use pattern of the city. For these reasons, the developing targets of urban transportation systems required by planners and administrators are the most complete [3]. They involve all the aspects in figure 2. The operators and users of urban transportation systems only partially participate in the urban transportation. As to the operators of urban transportation systems, which are often companies and enterprises, the developing the target of urban transportation system is to provide for the society the best transportation services with the lowest costs, that is, to realize the maximum ratio of "benefit/cost" during the operational process of the companies. From the aspects of users in the urban transportation systems, what they are concerned most with is the extent to which the urban transportation system can satisfy their demands of swiftness, safety, low costs and comfort in travelling. Therefore from the standpoint of those two interest groups, the anticipation to the developing target of the urban transportation system is incomplete. Generally speaking, it can reflect only partial benefits on their behalf. In the view of planners and administrators of the urban transportation system, this paper mainly analyzes the factors of urban transportation efficiency and studies the corresponding evaluation target, index framework and method.

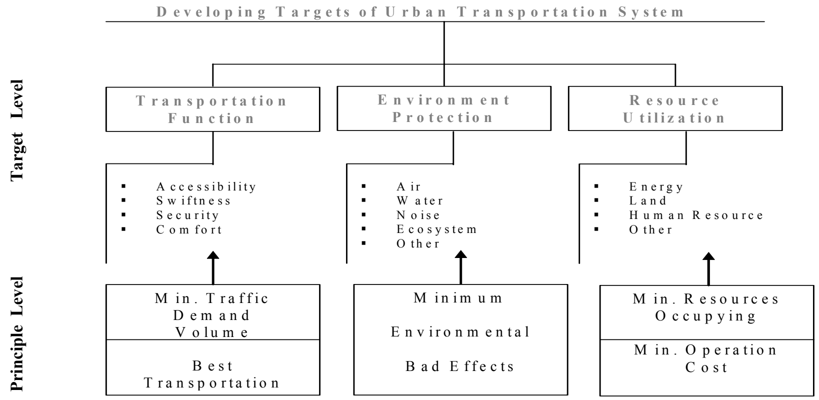

Figure 1: Developing targets of urban transportation systems.

4 Evaluation index frameworks and method

4.1 Key factors influencing urban transportation efficiency

To study the factors of transportation efficiency is the first step of evaluating urban transportation efficiency and proposing corresponding countermeasures. In this paper, the impact factors of urban transportation efficiency are mainly divided into four aspects, which are urban land-use pattern, transportation structure, transportation infrastructure, and traffic management system.

4.1.1 Urban land-use pattern

Urban land-use pattern means the characteristics and intensity of land-use activities. Transportation demand is derived from the producing and living activities of the population.

Therefore under a certain economic level and land-use pattern, the generation/attraction intensity and spatial distribution of transportation demand have basically been determined.

Urban transportation efficiency varies with different land-use patterns greatly. Therefore, in order to improve urban transportation efficiency, it is an essential measure to build a suitable urban land-use pattern, which can decentralize urban functions, balance the distribution of transportation demand, cut down on total traffic volume and relieve traffic congestions in cities.

4.1.2 The structure of urban transportation systems

Under a certain land-use pattern, the total capacity of the urban transportation system is basically determined by the composition of different transport modes in the system. Whether the structure of the urban transportation system is harmonized with the land-use pattern, will directly impact the balance between transportation demand and supply. Given the total amount of transportation demand and a certain level of transportation infrastructure in a city, a good transportation structure will most effectively utilize the infrastructure and will help fully realize the functions of urban transportation systems.

4.1.3 Urban transportation infrastructure

Urban transportation infrastructure mainly includes roads, parking lots, vehicles and transportation terminals. It is the direct carrier of urban transportation demands and the basic input of the capacity of transportation supply. From the viewpoint of the relationship among transportation efficiency, input and output, the operational efficiency of transportation infrastructure is the key factor which will directly influence the urban transportation capacity provided by the system.

4.1.4 Urban traffic management system

An urban traffic management system is an important component which can properly control and guide the distribution of traffic flows on roads, and can help improve the urban environment. Even if the urban transportation infrastructure in different cities is at the same level, the capacity of urban road systems may vary greatly with different traffic management systems. For example, according to our surveying of some main intersections in Beijing, capital of China, most of them have a queue of more than 200 meters during the morning and evening peak hour. And the average delay of motor vehicles at these intersections is about 2 or 3 minutes. However, the actual highest traffic volume of these intersections is only 60%~80% of that at similar intersections in developed countries. Therefore, given a certain land-use pattern and transportation structure in a city, a traffic management system then becomes the key factor to determine the level of transportation efficiency and the relationship between transportation demand and supply.

4.2 Evaluation method

One of the main problems confronting the evaluation of urban transportation efficiency is that there is not a determined and absolute criterion to be referred. For example, although the idea of "giving priority to public transportation" has commonly been accepted by most countries, people can not exactly know how much the optimum share of public transport mode should be. Only relative comparison and evaluation can be given out. For another example, each city has its unique characteristics in size, land-use pattern, and transportation structure, etc. Therefore the same evaluation index will have different criteria when it is applied in different type of transportation systems. The uncertainty of evaluation criteria is the most important problem needs to be solved. There are two methods to solve such a problem. The first one is to classify cities according to their size before evaluation. This will eliminate the uncertainty caused by the difference of sizes among cities and improve the comparability among different systems. The second one is to adopt fuzzy theory to reduce uncertainty. When using fuzzy evaluation methods, the key step is to build a set of valuable objects. Two possible methods can be adopted. The first one is to evaluate and compare the transportation efficiency in the context of different developing periods of a single city. The second one is to compare and evaluate the transportation efficiency of different cities in the same period. The outcome of the former method depends on the absolute evaluation criteria, which could be obtained by referring to the corresponding figures of typical cities with similar size in other countries. For the second method, the reference frame could be composed by the optimal figures chosen from those of the cities to be evaluated.

4.3 Logic models

Logic models are an evaluation framework commonly used in the social sciences. They use diagrams that show the major components of a program, with arrows illustrating relationships between input, outputs and outcomes. Logic models also include a narrative that explains the relationships between these components and identifies external factors that can affect the program's effectiveness. A Logic Model helps answer questions such as, "What is this program trying to achieve and why is it important?" and "How will we measure effectiveness?" The answers can help meet accountability requirements and identify ways to improve the program.

Inputs: "*What we invest*"==> Outputs: "*What we do*" "*Who we reach*" ==> Outcomes: "*What difference it makes*"

The steps involved in creating such a framework are described below:

1. The first step is to describe the problem that the program is intended to address and collect information about it. It is important to understand the problem from clients' perspective and factors that affect the problem. For example, traffic risk can be evaluated in several different ways which give very different conclusions about the nature of the problem Safety Evaluation. It can be measured per vehicle-mile, per passenger-mile, per motor vehicle, or per capita.

2. The second step is to identify the major components of the program's outcomes, including long-, medium- and short-term effects. Long-term outcomes might include changes in social, economic, and environmental conditions. For example, one long-term, social outcome for a traffic safety program is improved public health (fewer injuries) in an area. A long-term, economic outcome might be a reduction in health care costs.
3. The third step in creating a logic model is to organize the outcomes in a sequence or chain of events and to identify external factors which can hinder or facilitate the program.
4. The fourth step in developing a logic model is to specify the process theory. The process theory has two main components: the program's service utilization plan and its organizational plan. The service utilization plan is a flowchart that shows how clients (or specific groups of clients) become engaged in the program's activities. The key idea is to describe how the program involves the client from his or her perspective.

5 Conclusions

Management experts often say that, "you can't manage what you can't measure." What is measured, how it is measured, and how data are presented often affects how problems are defined and solutions evaluated. A particular solution may appear best when measured one way, but undesirable when measured another way.

Urban transportation efficiency is the key factor which determines the capacity of urban transportation systems and the balance between transportation demand and supply. The transportation input (i.e. construction of transportation facilities) cannot increase within a short period of time, but the demand of transportation is growing rapidly. Therefore to improve the efficiency of urban transportation systems is the best way to effectively utilize the existing inputs, enhance the capacity of the systems and relieve urban traffic congestion. Among the factors influencing urban transportation efficiency, the effects of urban land-use pattern and transportation structure are chronic and long term, while those of urban transportation infrastructure and traffic management systems are obvious and short term. This has resulted that the evaluation of urban transportation efficiency may involve many indices, many of which are highly uncertain or complex.

References

[1] Glenn D. Israel, Using Logic Models for Program Development, Cooperative Extension Service, University of Florida (http:// edis.ifas.ufl.edu /BODY_WC041), 2001.

[2] Song, B., Zhang, Y., and Bu, G. (1999) Grey Comprehensive Evaluation Method for Optimal Level Value in Fuzzy Optimization Problem, Theory and Practice of Systems Engineering, No.5, 100-104.

[3] Zhou, T. (1997) Efficiency and Supply-side Economics. Economy and Sciences Publishing Company, Beijing