Evaluation on Route Guidance System and Its Application

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Abstract

Route guidance system (RGS) is widely used as one of main measures of Intelligent Transportation System, which means to maintain an acceptable service level for mobility of persons and goods. But the traffic benefits brought by RGS vary a lot with the characteristics of road networks and traffic flow. Then how to evaluate the traffic benefits is of importance to its implementation. The paper analyzed traffic benefits of RGS. Evaluation Measures of Effectiveness (MOEs) of RGS and its definition models are put forward. An application of the research results is performed with TESS (Tongji transportation nEtwork Simulation System). Comparison of outputs from TESS and VISSIM is provided, which proved the validity of the research. The research is important for evaluation of RGS and integration of RGS and other traffic management and regulation measures.

Key words: Route Guidance System (RGS); Evaluation Measures of Effectiveness (MOEs); Travel time; Simulation

0 Introduction

With the rapid development of social economics, the relationship of supply of the infrastructure and travel demand is becoming unbalanced, which in turn deteriorate the service level of road transportation system. Thereupon, kinds of measures, based on making full use of road infrastructure, have been applied to improve transportation service, in which Route Guidance System (RGS) is widely used in America, Europe and Japan. And then, research on how to evaluate traffic benefits of RGS are of importance to optimizing implementation and extending market penetration, which is focus of this paper.

1. Literature review

Route guidance system integrating technologies such as computer and communication helps driver find one or more routes from a certain origin to a certain destination and provide real-time traffic information. It has been about forty years since route guidance system became the research focus. Most achievements can mainly be included in the following three kinds: optimization of guidance strategy, benefits analysis, and factor analysis that affects guidance benefits.

(1) Researches on guidance strategy

The main function of route guidance is to help traveler select reasonable routes for less travel cost by providing traffic information. Meanwhile, the simple strategies in the selection of information, which designate the shortest route from A to B, could have an adverse effect on traffic flows, which are over-saturated reaction, concentration reaction, and collective reaction (Ben-Akiva et al.1991). In order to solve these phenomenon, a number of approaches have been proposed which can be described as three types. The first type is called iterative (or predictive) and uses complex simulation models to predict the future consequences of the routing actions on network conditions (Ben-Akiva et al., 1997), which are designed to simulate the users reactions to the messages sent and to predict, in real time, the flows in the network according to the information supplied to users. However, it is influenced by the effectiveness of traffic models and requires long computation time. As an alternative, reactive routing strategies, applicable in the urban context, have been developed (Papageorgiou and Pavlis, 1999). They are based on the feedback concept and react to traffic conditions, observed in real time, in order to lead the system towards an objective state. Explicit prediction models of user behavior following control actions are therefore avoided. And decentralized (or distributed) structures have been adopted, so that each controller of the system can operate only on local variables (Gallager, 1977).

The third type is a particular strategy recently proposed which is a decentralized and feedback routing strategy, based on the concept of instantaneous travel time, calculated in real time by measuring traffic. No information on the predicted state of the network (traffic flow on the arcs) or on travel demand (O – D matrix) is required (Francesco Paolo Deflorio, 2003).

The first type is based on predictive traffic information, while the last two types are based on real-time traffic information.

(2) Analysis of guidance benefits

Research on benefits of route guidance system appeared with the application of RGS and its market penetration. Early research by TRRL(Transport and Road Research Laboratory) proved that it reduces vehicle mile by 8%~10% if drivers comply with the shortest route information. Levinson, David. (2003) found that travel time saving from guidance ranges from 2.7% to 55% according to relevant research, and proved that time saving is more extinct during incidents by using stochastic queuing model. Karl. E. Wunderlich et al. (2001), using experiments, also proved that the benefits are mainly on user's time schedule, which means that travel reliability is improved obviously. By using simulation, Yang (1998) proved that time saving from guidance strategy based on real-time information is more effective, while as to solving over-saturated reaction strategies based on predictive information is more useful.

(3) Factors that influence guidance benefits

Aldeek et al. (1991) revealed that during recurrent traffic congestion benefits from guidance is very limited if only a few vehicles are equipped with guidance system. Huang et al. (2002) believed that it is not certain that individual travel cost can be reduced by providing traffic information, which are dependent on the factual traffic situation on road networks and capacity of each route. And sensitivity analysis among market penetration, update frequency, flow prediction, and over-saturated reaction has been performed by Kaysi(1992), Yun (2004) discussed further about the influence of road networks capacity to guidance benefits. All these researches are helpful in understanding benefits of route guidance.

(4) Summary

From above, as to route guidance system, information providing and traveler behavior both are important, which in turn influence effect of route guidance. So as to evaluation of route guidance system, how driver react to information directly influence the system's effect. Moreover, research results from simulation in other countries can hardly describe the fact in most cities in China, which is mainly due to two kinds of reasons listed as following.

① Characteristics of traffic systems are different

Different with motorized cities, most cities in China are during a motoring process, in which travel behavior, traffic flow, and even road networks all present different characteristics.

② Travel behavior varies in different areas

Discretionary activities and commuting patterns differ in each city, so results from experiments and simulations in other cities abroad are not fit for the fact in China, which brings the necessity to evaluate the benefits of RGS.

③ Measures of evaluation are not fully considered

Questions such as what MOEs are reasonable and if the MOEs can completely show the whole benefits are not deeply studied yet.

2 Definition of evaluation measures

2.1 Selection of evaluation measures

Selection of MOE for RGS should consider the following rules (Yun, 2004):

（1）traffic benefits of RGS not only include travel time saving, but also time schedule reliability improvement that can reflect travelers' perception to the service of traffic system.

Karl E. Wunderlich analyzed real time reliability of RGS and drew the conclusion that traveler can get more benefits when reliability and prediction is improved.

(2) benefits from RGS include not only travel time saving from travelers, but also improvement of networks efficiency for administrators.

(3) As to traffic benefits, both guidance users and non-guidance users should be considered.

2.2 Determination of MOEs

With consideration of above three rules, MOEs of RGS benefits are listed in four kinds, efficiency, safety, comfort, and environment, which are shown in table 1. The MOEs are from the view of travellers and the whole networks.

Table 1. MOEs of RGS benefits

Types \ MOEs \ Subjects	Travelers	Networks
Efficiency	(1) average travel time	(2) total travel time
	(3) average delay	(4) total delay
	(5) average velocity	(6) network velocity
	——	(7) network saturation
Safety	——	(8) death rate
	——	(9)incident delay (damage)
Comfort	(10) reliability	——
	(11) punctuality	——
	(12) information reliability	(12) information reliability
Environment	——	(13) fuel consume
	——	(14) pollution exhaust
	——	(15) noise

Take average travel time T as an example, T includes travel time of road link (T'_l) and intersection delay (d_k), then $T = T'_l + d_k$.

Average travel velocity (V) can be described as:

$V = \frac{V_f}{2} + \sqrt{\frac{V_f}{4} - \frac{V_f}{K_j} Q}$. Here V_f is velocity under free flow, K_j is maxim density of road links. Q is traffic flow. Then $T'_l = \frac{L_l}{V}$. Here L_l is length of road link l. As to intersection delay (d_k), it can be formulated as $d_k = \frac{r_k^2}{2c_k} \cdot \frac{S_l}{S_l - Q_l}$. Here d_k is intersection delay, r_k is red time, c_k is cycle time, S_l is saturated flow of road link, Q_l is factual flow of road link.

Then, travel time t_{ij} from i to j, in which there are m road links and n intersections included, is

$$t_{ij} = \sum_{l=1}^{m} T'_l + \sum_{k=1}^{n} d_k .$$

Average travel time (T) is weighted average travel time of vehicle flow, formulated as:

$$T = \frac{1}{\sum_{i=1}^{n}\sum_{j=1}^{m} Q_{ij}} \times \sum_{i=1}^{n}\sum_{j=1}^{m} t_{ij} \times Q_{ij}$$

. Here Qij is traffic flow from i to j. Detailed determination of each MOE can refer to the relevant research (Yun, 2004).

3 Model validation based on TESS and VISSIM

In order to validate the applicability of determination of MOEs, TESS (Tongji transportation nEtwork Simulation System) is applied here which is a time space discrete micro-simulation that means to analyze urban arterial networks with consideration of information provision and above models are used in TESS. Further research on TESS is still going on in our research team (Sun, 2005). At the same time, micro-simulation VISSIM is applied, which is a popular microscopic simulation model produced by PTV in German. The main output of TESS and VISSIM selected here includes travel time, speed, queue, and delay. At the same time, Travel time of RGS users and non-users are selected here and comparison of outputs by TESS and VISSIM is performed. The test network is in Hangzhou shown in figure 1, and comparison by VISSIM and TESS is shown in figure2. The results from TESS and VISSIM are closely correlative, which reveals that TESS is also a useful tool in the analysis.

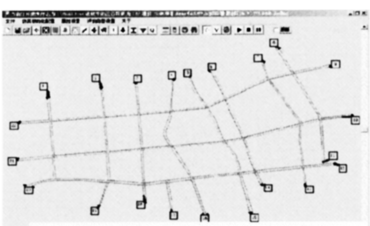

Figure1. Test network in the city of Hangzhou

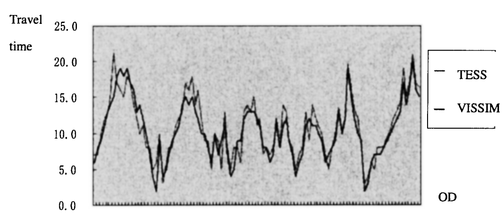

Figure 2. Travel time comparison of OD pairs

Car and bus are both considered in the test with 90% and 10% respectively, which both include RGS users and non-users (TRaditional, TR) accounting for 60% and 40 apart. RGS users are described as Pre-trip information Servicing (PS) and on-Board Routing (BR). The rates of TR, PS, and BR are 2:5:3. Average travel time of the above three users, in condition that 27 OD pairs are considered, is shown in figure 3. The outputs show that usually velocity of BR users is higher than PS users, and velocity of non-RGS-users is the lowest. However, velocity of some OD pairs turns out different conclusions, that probably due to the nonproficiency of simulation model.

4 Conclusions

To identify traffic benefits of RGS, measures of effectives and its determination models are presented in consideration of four types of guidance users. Then VISSIM and TESS are performed to validate the models, and comparison of outputs by VISSIM and TESS is provided that confirms the research results.

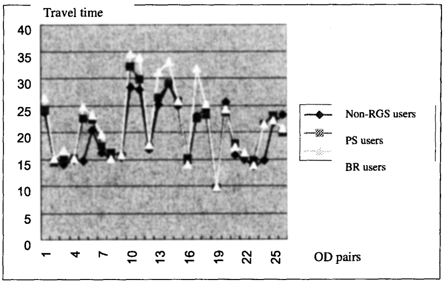

Figure 3. Average travel time of different kinds of users by VISSIM

References

A. Kanafani and H. Aldeek, 1991, A simple model for route guidance benefits, Transpn. Res. 25B, 191-201.

Ben-Akiva, M., A. De Palma, and I. Kaysi, 1991, Dynamic network models and driver information systems. Transpn Res. 25A, 251-266.

Francesco Paolo Deflorio, 2003, Evaluation of a dynamic route guidance atrategy, DITIC - Polytechnic of Turin, Italy.

Gallager R. G. 1977, A minimum delay routing algorithm using distributed computation. IEEE Transactions on Communications, vol. 25, No1, 73-84.

HUANG Hai-jun, WU Wen-xiang, 2002, Models for evaluating impacts by travel information systems on travel behavior. System engineering, 10, 81-83.

karl E. Wunderlich, Matthew H. Hardy, james J. Larkin, Vaishali P. Shah, 2001, On-time reliability impacts of Advanced Traveller Information Services (ATIS): Washington, Dc Case study.

Kaysi, I., 1992, Frameworks and models for the provision of real-time driver information, Ph.D. thesis, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge MA.

Levinson David, 2003, The value of advanced traveler information systems for route choice, Transpn Res. -C, 75-87.

Papageorgiou M. and Pavlis Y. 1999, Simple decentralised feedback strategies for route guidance in traffic networks. Transportation Science, Vol. 33, No. 3, 264-278.

Sun Jian, Yang Xiaoguang, 2005, A Simulation-based approach to evaluate dynamic multiple user route choice behavior under ATIS, the 5th international conference on traffic and transportation academy, Xi'an.

Yang, H. 1998, Multiple equilibrium behaviors and advanced traveler information systems with endogenous market penetration. Transpn Res. 32B, 205-218.

Yun Meiping, 2004, Study on evaluation methods of traffic benefits for Advanced Traffic Management Systems (ATMS), Ph.D. thesis, Tongji University, Shanghai, China.