Journal of System Simulation

Volume 27 | Issue 8 Article 33

8-3-2020

Application of FLOWSIM for Traffic Management and Assessment in Shenzhen

Yuhan Jia
Department of civil engineering, Tsinghua University, Beijing 100084, China;

Jianping Wu
Department of civil engineering, Tsinghua University, Beijing 100084, China;

Yiman Du
Department of civil engineering, Tsinghua University, Beijing 100084, China;

Geqi Qi
Department of civil engineering, Tsinghua University, Beijing 100084, China;

Application of FLOWSIM for Traffic Management and Assessment in Shenzhen

Abstract

Abstract: Recently many traffic problems are faced by more and more cities. Since traditional method can no longer solve the above problems, and Transportation Demand Management (TDM) solutions are in desperate need. Also, as a successful application of Intelligent Traffic System (ITS), traffic simulation software has become an efficient way to carry out assessment for TDM. The implementation of *congestion charge policy* in Shenzhen was studied as a demonstration of TDM in China. Then the microscopic traffic simulation software, *FLOWSIM*, was introduced to simulate the traffic situation to *do assessment of congestion charge*. Based on the results, advices were given and further research plans were discussed.

Keywords

traffic simulation, FLOWSIM, traffic management and assessment, congestion charge

Recommended Citation

Jia Yuhan, Wu Jianping, Du Yiman, Qi Geqi. Application of FLOWSIM for Traffic Management and Assessment in Shenzhen[J]. Journal of System Simulation, 2015, 27(8): 1881-1887.

第 27 卷第 8 期 系统仿真学报© Vol. 27 No. 8
2015 年 8 月 Journal of System Simulation Aug., 2015

Application of FLOWSIM for Traffic Management and Assessment in Shenzhen

Jia Yuhan, Wu Jianping, Du Yiman, Qi Geqi

(Department of civil engineering, Tsinghua University, Beijing 100084, China)

Abstract: Recently many traffic problems are faced by more and more cities. Since traditional method can no longer solve the above problems, and Transportation Demand Management (TDM) solutions are in desperate need. Also, as a successful application of Intelligent Traffic System (ITS), traffic simulation software has become an efficient way to carry out assessment for TDM. The implementation of *congestion charge policy* in Shenzhen was studied as a demonstration of TDM in China. Then the microscopic traffic simulation software, *FLOWSIM*, was introduced to simulate the traffic situation to *do assessment of congestion charge*. Based on the results, advices were given and further research plans were discussed.

Keywords: traffic simulation; FLOWSIM; traffic management and assessment; congestion charge

FLOWSIM 在深圳交通管理与评价中的应用研究

贾宇涵，吴建平，杜怡曼，奇格奇

（清华大学土木工程系，北京 100084）

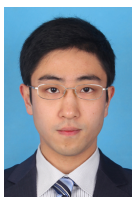
摘要：近年来我国城市交通问题愈发严重，传统的交通解决方法已经无法解决目前的城市交通困境，因此很多新型的交通需求管理方法呼之欲出。交通仿真软件等一些智能交通系统的应用也能够解决很多交通管理与评价难题。以深圳为例，研究了大城市实施*拥堵收费*的可能性。针对收费后可能出现的情况，采用微观交通仿真软件 *FLOWSIM*，进行了*拥堵收费*的仿真模拟和效果*评价*，提出了一些有价值的建议。研究表明:交通仿真软件 FLOWSIM 为大城市应用 TDM 解决交通问题的相关研究提供了新思路和新方法。

关键词：交通仿真；FLOWSIM 仿真软件；交通管理与评价；交通拥堵收费

中图分类号：U491.2 文献标识码：A 文章编号：1004-731X(2015) 08-1881-07

Introduction

With the fast development of economy in China, vehicles have increased rapidly in many cities, leading to a lot of traffic problems. Every day we are facing traffic jams, accidents and vehicle emission more than ever in history. So it is very critical for decision makers to take various kinds of traffic management and control measures. It should be noticed that currently the traditional actions, such as enlarge the traffic demand, can no longer solve above problems [1-2]. So instead of focusing on how to meet the traffic demand, managing traffic demand is becoming the hot spot for researchers recently. Transportation demand management (TDM) means the actions aimed at influencing drivers' behavior to decrease the



Received: 2015-04-27 Revised: 2015-06-18;
Project: Beijing Natural Science Foundation (9132010); China Post-doctoral Science Foundation (2013M540102);
Authors: JIA Yu-han (1989-), male, Liaoning, Ph.D. student, research area: traffic simulation, ITS; WU Jian-ping (1957-), male, Zhejiang, doctor, professor, research area: ITS, traffic environment; DU Yi-man (Corresponding author, 1977-), female, Sichuan, doctor, research area: traffic simulation, traffic control.

need of vehicles and increase the usage of alternative mobility options [3-4]. TMD requires many actors, including policy developers, landowners, business companies and all levels of government [5]. There are many kinds of TDM policies, like congestion charge, vehicle tail number restriction, license-plate lottery and so on. Also, it is observed that the design and assessment of traffic plans must be developed off-line for cost saving and risk avoidance. As a result, traffic simulation tools are becoming of increasing importance. As one of the most successful applications of Intelligent Traffic System (ITS), several simulation tools are widely used, such as AIMSUN, VISSIM and FLOWSIM [6-9]. By simulation, traffic management authorities can pre-evaluate the performance of TDM solutions.

This paper focuses on the application of microscopic traffic simulation software FLOWSIM in Shenzhen to evaluate the congestion charge policy as a TDM demonstration in large cities in China. The background of congestion charge and traffic simulation is introduced in section 2. Section 3 gives the congestion charge plans in Shenzhen and also the simulation solutions for pre-assessment. Then the analysis of simulation results and discussions for congestion charge are described in section 4. Finally, the last section is the summary and further study plan.

1 Background

Shenzhen is located in southern China, occupying about 1,991 square kilometers with 10.63 million permanent residents. Shenzhen is the first special economic zone in China, established in 1980 by the leader Deng Xiaoping, and since then Shenzhen has been the touchstone for the country's reform and opening-up policy. As one of China's most important gateways to the world, this city is one of the most developed and fastest-growing cities in the world. Shenzhen is the high-tech and manufacturing hub of southern China, home to the world's third-busiest container port, and the fourth-busiest airport on the Chinese mainland. As a State-level innovative city, Shenzhen has chosen independent innovation as the dominant strategy for its future development.

With a booming economy, however, Shenzhen is facing more traffic problems than ever. With an increase of 534 thousand vehicles in 2014, the rate of car ownership in Shenzhen is comparatively high among China, making the total vehicle number more than 3 million by the end of last year. Besides, many nonlocal vehicles have also contributed a lot to Shenzhen's traffic problems. As a result, the ribbon-form city cannot hold so much traffic, causing serious traffic congestions, accidents and exhaust gas.

To solve the aforementioned traffic problems, many innovative methods should be carried out, such as congestion charge, tail number restriction, license-plate lottery and so on, to realize TDM in Shenzhen. Worldwide speaking, many pilot cities have already implemented the congestion charge policy for several years, like Singapore and London. In China, there are also many cities researching and preparing to launch relevant policies. Being a State-level innovative city, Shenzhen should be the pilot to study projects and policies on congestion charge.

Congestion charge can be defined as the dead-weight loss of inefficient pricing of scarce road resources [10]. In 1975 the first congestion charge system was implemented in Singapore named as Area Licensing Scheme (ALS). And in 1998, Electronic Road Pricing (ERP) replaced former system. Drivers have to purchase a whole-day license or a part-day

license to enter the restricted area [11]. In 2003 London Congestion Charging Scheme (LCCS) was also implemented as a large-scale congestion charge project. LCCS is an area-licensing scheme covering 22 square kilometers in central area. The system works from 7:00 to 18:30 on workdays based on video cameras and all the vehicles appear in the zone have to pay the charge [12]. Both Singapore and London also improved the public traffic system to complement the congestion charge policy. So far, congestion charge policy has helped to improve traffic condition in the two cities.

For the assessment of congestion charge, the microscopic traffic simulation software FLOWSIM is introduced in this study. This simulation tool is built with fuzzy logic based motorway model. Many researches have emphasized that with fuzzy driving behavior models, FLOWSIM can replicate real traffic systems better [7-8]. The fuzzy logic based models mainly contain car-following model and lane-changing model. It was first developed in University of Southampton and put into application in many European cities, and now has moved to China. Unlike other simulation tools, FLOWSIM has finished the data collection in China and the model has been calibrated and validated to simulate the mixed traffic flow [13]. Now FLOWSIM has been tested in many cities to carry out traffic management and evaluation, dynamic simulation, traffic environment control and so on [14-15].

2 Charge plan and simulation

According to the congestion charge theory, the study area should be a main road or zone where serious traffic congestion happens periodically. After field survey, Caitian Road is decided as the charging area, which is a north-south main road carrying a lot of traffic flow every day. The study area is 4 kilometer long, from the Huanggang-Caitian Overpass to Shennan Road. It is noticed that Huanggang Road is a parallel main road besides Caitian Road and both roads are loaded with much traffic as they are the main paths to travel in and out of Hong Kong. So Huanggang Road should also be included in study area for it will be influenced when Caitian Road is under congestion charge. The study roads are shown in Fig. 1, and the average traffic flow data in morning peak hour are listed in Table 1 where v/c means traffic flow rate divided by road capacity.

Fig. 1 Study area and simulation surface of FLOWSIM.

Table 1 Traffic flow data in study area

	From N to S		From S to N	
	Traffic flow	v/c	Traffic flow	v/c
Caitian	3590 pcu/h	0.82	2057 pcu/h	0.47
Huanggang	2750 pcu/h	0.71	1640 pcu/h	0.42

The study area includes 5 large overpasses and 5 signalized intersections, making it one of the most congested areas in Shenzhen. The congestion charge system will be based on the existing License Plate Recognition System (LPRS) along Caitian Road to identify passing vehicles. It is verified that with upgraded HD cameras, the recognition rate of LPRS is more than 95%. The charging time is set from 7:30 to 9:30 and from 17:30 to 19:30, and in each period every passing vehicle will be identified and charged only once. The fee will be taken automatically from an associated credit card and the driver can pay it off afterwards. It should be noticed that special purpose vehicles are excluded from charging, such as public bus, taxi, ambulance, police car and so on.

However, there remain some critical questions. First, how much the traffic situation will be improved on Caitian Road after charging. Second, to what extent the traffic congestion will be aggravated on Huanggang Road since part of the traffic to Hong Kong will be transferred from Caitian Road to it. It is very difficult to do the pre-assessment for Shenzhen without the help of ITS. So in this study, FLOWSIM is introduced to run simulations to help the decision makers.

FLOWSIM has many kinds of user-oriented toolboxes for modeling procedure. First, the map of study area is imported as the background layer and roads, intersections and overpasses are modeled the same scale as field. Then the property of each traffic infrastructure is set, such as lane number, speed limit, road capacity. For intersections, traffic signals and road channelization are also modeled in FLOWSIM based on field survey. Finally, the traffic flow data, like OD matrix for various traffic modes, is imported into the model database. After modeling and data input, the study area in FLOWSIM is also shown in Fig. 1.

The morning peak hour 7:30~9:30 is selected as simulation period to study the influence before and after congestion charge. First, we sun several simulations to validate the accuracy of FLOWSIM without charging. The average speed is chosen as the index for comparison and the average simulated speed and field speed are listed in Table 2. Form the results it is observed that FLOWSIM can reflect the real traffic situation objectively. Therefore, FLOWSIM can be furthered used in this research to run simulations considering congestion charge.

Table 2 Simulated data and field data

	From N to S (km/h)		From S to N (km/h)	
	Simulated	Field	Simulated	Field
Caitian	36.6	35.9	33.4	32.3
Huanggang	31.8	30.1	32.8	30.8

After congestion charging, the existing traffic situation will be quite different, for part of the vehicle drives will chose to travel by other traffic mode like public bus, and part of the cars will go for Huanggang Road to finish the journey, also some of the traffic demand will be shifted to non-peak hour after congestion charge. So the OD matrix must be adjusted according to the charge fee, listed in Table 3.

Table 3 Adjustment on traffic demand

Charge	Caitian	Traffic transferred to:		
fee	Reduction	public traffic	Huanggang	other time
Low	5 - 10 %	10 %	80 %	10 %
Moderate	10 - 20 %	25 %	60 %	15 %
High	20 - 30 %	35 %	50 %	15 %

In FLOWSIM, each of the three congestion charge plans is simulated for 10 times during morning peak hours and the average results are calculated to reduce the random error. To carry out the assessment accurately, two traffic flow parameters, average speed and travel time, are selected as comparison indexes.

3 Results and discussion

After simulation, the preset traffic flow characteristics could be calculated by FLOWSIM. The simulated average speed data is listed in Fig. 2, where N to S represents from north to south and S to N means from south to north. It is observed that the traffic situation on Caitian Road is improved in all the three cases after congestion charging, while vehicles on Huanggang Road are slower than before. The average speed for vehicles on Caitian Road is increased by 5.8 %, 14.4 % and 18.8 % from north to south, and by 7.3 %, 9.6 % and 14.8 % from south to north, when the charge fee is low, moderate and high, respectively. For Huanggang Road, this index is reduced by 5 %, 12.5 % and 21.5 % from north to south, and 9.1 %, 14.5 % and 21.5 % from south to north for the three conditions, respectively.

The second index, average travel time, is listed in Fig. 3. It is noticed that the average travel time before and after congestion charge show the same trend as Fig. 2. When charging, the travel time on Caitian Road becomes shorter while on Huanggang Road longer. For Caitian Road, this index is increased by 11.1 %, 16.8 % and 23.0 % from north to south, and 4.4 %, 16.1 % and 21.8 % from south to north for the three conditions, respectively. For Huanggang Road, the reductions are 13.6 %, 28.3 % and 44.2 % from north to south, and 8.8 %, 16.0 % and 27.3 % from south to north. Also, with increasing charge fee, the time reduction and growth percentage become larger.

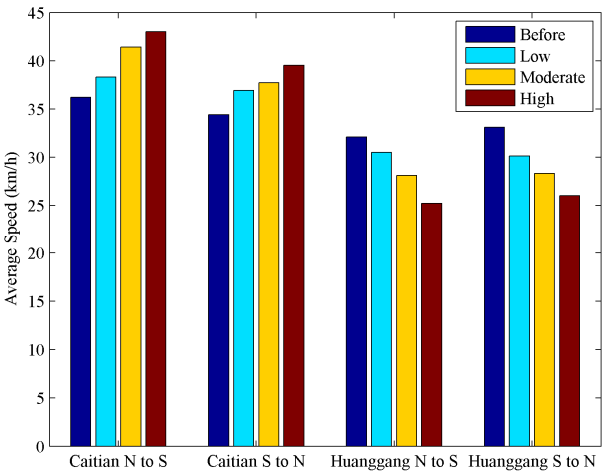


Fig. 2 Simulated average speed before and after charge

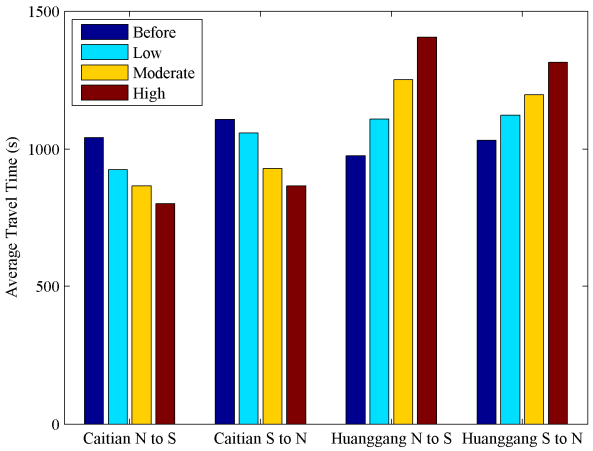


Fig. 3 Simulated average travel time before and after charge

From the results, it is concluded that with congestion charge, the traffic situation on Caitian Road could be improved, but on Huanggang Road both average speed and average travel time become worse than before. So how to deal with this situation on Huanggang Road remains as a problem. What's more, there are some other concerns about congestion charge. First, part of the vehicle drivers on Caitian Road will shift to travel by bus, but the current supply of public traffic cannot meet the need. Second,

about 10 % of the vehicles on Caitian Road are non-local cars, making it difficult to inform the drivers to pay the fee. Also, in study area there are many residential districts and office buildings, so they will be influenced seriously for they have to travel along Caitian Road several times every day. Last, after charging there might be some lawbreakers who will cover the plate or use fake plate to dodge the expense.

In conclusion, to make sure the congestion charge policy runs smoothly, the charge fee should be investigated carefully to ensure the policy effect as well as reduce the impact on Huanggang Road. Also, the public traffic system must be upgraded to enlarge the supply for commute travel. Then some propaganda projects should be carried out to inform non-local drivers and to prevent the potential lawbreakers. Besides, for the residents and workers in charging area, discount should be provided to reduce the negative influence.

4 Summary and further study

With the high speed of economic development in China, some innovative policies are in great need to solve the increasingly heavy traffic problems. As one of the TDM solutions, congestion charge is considered as practical, cost saving and feasible technically. In this paper, the implementation of congestion charge is studied in Shenzhen as a demonstration and the pre-assessment is investigated by the introduction of microscopic simulation software, FLOWSIM. Work so far has shown that FLOWSIM can reflect the traffic situation objectively in Shenzhen. Then many simulation tests are launched to compare two traffic flow characteristics, average speed and average travel time, before and after charging. What's more, the charge fee is divided into three cases, as low, moderate and high. From simulation results, it is concluded that on Caitian Road the traffic situation is improved obviously, while on Huanggang Road both traffic flow parameters become worse than before. Besides, this trend turns to be more significant as the charge fee increases. Also, more measurements should be considered to ensure the congestion charge policy, such as the supply for public traffic should be enlarged, actions should be taken to deal with non-local vehicles and lawbreakers.

This study shows that with the help of FLOWSIM simulation, TDM policies could be evaluated even before implementation, which can act as a reference for authorities in other cities in China. However, only two roads are considered in this paper to assess the congestion charge policy. In further study, regional simulation should be investigated taking more roads and intersections into account. Also, more scenarios should be tested when the charging area is expanded from a certain road to a large zone.

Reference:

[1] Brackstone M, McDonald M. Car-following: a historical review[J]. Transportation Research Part F: Traffic Psychology and Behaviour (S1369-8478). 1999, 2(4): 181-196.

[2] Papageorgiou M. Some remarks on macroscopic traffic flow modelling[J]. Transportation Research Part A: Policy and Practice (S0965-8564), 1998, 32(5): 323-329.

[3] Meyer M D. Demand management as an element of transportation policy: using carrots and sticks to influence travel behavior[J]. Transportation Research Part A: Policy and Practice (S0965-8564), 1999, 33(7): 575-599.

[4] WANG Feng-yuan, CHEN Yin-san, SONG Nian-xiu. Application of travel demand management in China [J]. Journal of Traffic and Transportation Engineering (S1671-1637), 2002, 2(2): 83-87.

[5] Ferguson E. Transportation demand management planning, development, and implementation [J]. Journal of the American Planning Association (S0194-4363), 1990, 56(4): 442-456.

[6] Min Guo, Yiman Du and Jianping Wu. The Basic Theory of Microscopic Traffic Simulation and its Applications

[M]. Beijing: China Communications Press, 2012.

[7] Jianping Wu, Mark Brackstone and Mike McDonald. Fuzzy Sets and Systems for a Motorway Microscopic Simulation Model [J]. Fuzzy Sets and Systems (S0165-0114), 2000(116): 65-76.

[8] J. Wu, M. Brackstone and M. McDonald. The validation of a microscopic simulation model: a methodological case study [J]. Transportation Research Part C: Emerging Technologies (S0968-090X), 2003(11): 463-479.

[9] Yiman Du, Jianping Wu, Geqi Qi, Yuhan Jia. Simulation of bicycle multi-phase crossing at intersections [J]. Transport (S0965-092X), 2015, in press.

[10] Santos G. Urban congestion charging: a comparison between London and Singapore[J]. Transport Reviews (S0144-1647), 2005, 25(5): 511-534.

[11] Goh M. Congestion management and electronic road pricing in Singapore[J]. Journal of Transport Geography (S0966-6923), 2002, 10(1): 29-38.

[12] Prud'homme R, Bocarejo J P. The London congestion charge: a tentative economic appraisal[J]. Transport Policy (S0967-070X), 2005, 12(3): 279-287.

[13] ZHANG Qing, GUO Min, WU Jian Ping. Study on application of FLOWSIM micro_simulation system for urban traffic [J]. Journal of Beijing JiaoTong University (S1673-0291), 2006, 30(6): 16-21.

[14] JIA Yuhan, WU Jianping, DU Yiman, QI Geqi. Study on FLOWSIM and its Application for Isolated Signalized Intersection Assessment [J]. Journal of System Simulation (S1004-731X), 2014, 26(10): 2529-2534.

[15] QI Geqi, WU Jianping, DU Yiman, JIA Yuhan. Traffic microcirculation scheme design of old quarter based on traffic simulation [J]. Journal of System Simulation (S1004-731X), 2014, 26(10): 2514-2518.

(上接第 1880 页)

[10] Hasseim A A, Sudirman R, Khalid P I. Handwriting classification based on Support Vector Machine with cross validation [J]. Engineering (S1947-3931), 2013, 5: 84-87.

[11] 姜明辉, 袁绪川, 冯玉强. PSO-SVM 模型的构建与应用[J]. 哈尔滨工业大学学报, 2009, 41(2): 169-171.

[12] 肖本贤, 王晓伟, 刘一福. MPSO-RBF 优化策略在锅炉过热系统辨识中的仿真研究[J]. 系统仿真学报, 2007, 19(6): 1382-1389.

[13] Shi Y H, Eberhart R C. A modified Particle Swarm Optimization [C]// Proceedings of the IEEE International Conference on Evolutionary Computation. Anchorage, Alaska, USA: IEEE,1998: 69-73.

[14] Clerc M, The swarm and the queen: towards a deterministic and adaptive particle swarm optimization [C]// Proceedings of the 1999 Congress on Evolutionary Computation (CEC 99). Washington, USA: IEEE, 1999, 3: 1951-1957.