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An urban traffic-environment model *

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Abstract—Urban environment pattern depends heavily upon urban traffic pattern, the balance between traffic (implicit production) and environment leads to the urban sustainable development. An integrated urban traffic-environment model consists of three components of urban production variables (population density, GDP, salary, etc. in blocks), urban traffic variables and urban environmental variables; and two links between urban traffic planning variables and urban environment variables, and between spatial interaction model (SIM) and traffic planning variables as well. The model is quite useful in urban environment impact assessment; urban traffic management; urban sustainable development planning; and urban development decision-making.
Keywords: SIM, urban environment, urban traffic planning, decision making.

1 Introduction

Urban sustainable development, population and GDP production, traffic, and environment are interacting with each other. Production of population and goods raise the need for exchange in space, leading to traffic flow. The traffic flow, in reverse, further enhance the production, and leads city to develop. In another aspect, traffic causes many environment problems that responsible for human diseases, this leads to form environment regulations that restrict the growth of urban traffic. An integrated model formed by the interaction of the subsystems is necessary for the prediction and management of the urban environment. The balance between the production and environment limitation forms one of major support for urban sustainable development, the solution to one problem must not lead to the creation of others (Hillier, 1998).

At first, to establish the links between production and traffic, and traffic and environment (Table 1), an integrated model formed, then, bi-direction prediction can be made using the integrated model by inputting production and consequently output environment, or inputting environment limitation and consequently output the traffic variables and further production (or urban growth). The simulation can be used for predicting possible impact both on urban environment by giving traffic planning or on traffic pattern by giving the new regulations on urban environment. That is just the tasks of planning and management of urban traffic and environment.

Table 1 From modeling to planning for the traffic-environment system

Attribute & Spatial	Modeling	Prediction	Planning
Production (people, GDP)			
Traffic			
Environment			

Note: the variables in the modelling consist of two aspects: attribute and spatial location. The fat arrows show that the models are used for prediction, and the predictions are used for planning. The directions of the line arrows show that the input and output in the models, prediction and planning. For instance, for modelling, the outputs in production model are put into traffic model, and the outputs of the traffic model are put into environmental model.

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2 Linking urban traffic and environmental variables

Traffic and environmental variables and their connections are clarified more specifically at first, then, their corresponding quantitative relationships are established.

2.1 Urban traffic-environment problems

The traffic variables of passengers, autos/networks, and stop/parks are heavily related with urban environment such as air pollution, noise, waste, congestion, occupation and diseases (Table 2).

Table 2 Relationship between traffic variables and environment variables

Impact on environment by urban traffic		Traffic variables		
		Passengers	Autos/Lines	Stop/Park
Urban environment variables	Air pollution		X	
	Noise	X	X	
	Waste	X		
	Crowd	X	X	X
	Space	X	X	X
	Disease	X		

Note: the "X" denotes which traffic variables are responsible for urban environment variables

For example, passengers are responsible for noise, waste, congestion, and diseases; stop and park occupy urban space and cause congestion; and autos and traffic network answer the air pollution, noise, and congestion. The different urban transportation modes (Mackett, 1998) are responsible for different environmental impacts but can be considered as a whole.

2.2 Quantitative relationship between traffic and environment

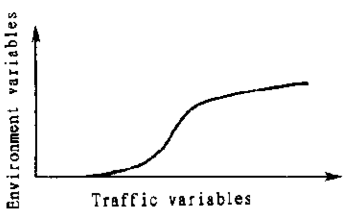

Fig. 1 Environment variables as a function of traffic variables

In order to link the traffic and environmental variables, quantitative relationship between them has to be established (Fig. 1). Ordinarily, the traffic volume exceeding a threshold will cause negative impact on urban environment, the environmental impact increases rapidly while the traffic increases until the environment are totally unsuitable for human inhibition. The quantitative relationship can be established by regressing observed traffic and environment variable data although before the regression some other mathematical techniques have to be used to separate the interaction among more than two variables.

3 Linking spatial interaction modeling (SIM) and urban traffic variables

The family of spatial interaction model is a very strong and flexible set of models for simulating, forecasting, and planning spatial flows such as traffic, goods, information, peoples, revenues, and so on.

3.1 SIM

The general formula for spatial interaction models is

$$\hat{T}_{ij} = V_i W_j F_{ij}.$$

Where $\hat{T}_{ij}$ is the estimated size (volume) of a flow (e.g. people, goods, money or information) from zone i to zone j, V_i denotes the origin factor, W_j the destination factor and F_{ij} the spatial separation factor. These factors are rather flexible to choice by considering the most related factors which origin the flow directly and most powerfully.

3.2 SIM for urban traffic planning

By traffic planning, we means: (1) planning traffic pattern (lines and network and their size); and (2) planning facility location and size (point). These tasks can be implemented by SIM (Fischer, 1996): (1) Trip distribution problems (e. g. forecasting traffic problems, trade pattern); (2) forecasting destination inflow totals (e. g. modeling shopping expenditures to forecast the revenues generated by particular shopping locations to determine the optimal size of a shopping development, facility location); (3) forecasting total outflows from origins (e. g. forecasting the effects of locating a new industrial park within a city, forecasting university enrollment patterns).

4 Linking SIM with urban environment-an integrated urban traffic-environmental model

First of all, a conceptual link of the subsystems are constructed, then an infrastructure to implement the links is designed, where I/O analysis is important, finally an integrated model formed.

4.1 Conceptual linkage

Traffic brings convenience and exchange to people and goods, although the traffic expense has to be paid for the benefit (Fig.2).

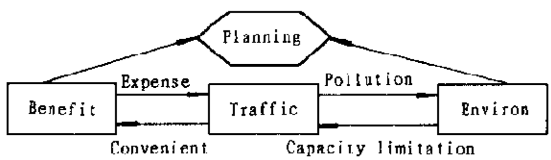

Fig.2 A conceptual linkage and integrated model of urban traffic-environment

Traffic disposes pollution to environment, and the limited environment capacity constrains the disposal. The balance between expected better economic situation and sound environment leads to sustainable development of a city. The key issue to develop an integrated urban traffic-environment model is to develop two links and to construct three components: link between urban environment and traffic, and link between spatial interaction model (SIM) and traffic planning. The three components are SIM, traffic planning and urban environment.

4.2 Infrastructure of the system

The three components have been well established and the two links are developed shown in the pretext, consequently, the key to construct the infrastructure of the integrated system is to clarify the input and output (I/O)for each subsystems, then they can be easily connected through dummy variables in subroutines.

4.2.1 I/O for environment-traffic model

Input data traffic (position, attribute)-traffic data (the position and attributes of traffic stop (point) and network (line)).

Transform parameters trans (traffic, environ)-link between traffic and environment (function of environment by traffic; Fig. 1).

Output data environ (position, attribute)- environment data (the position and attribution of air pollution, noise, waste, jam, and disease).

4.2.2 I/O for traffic-SIM model

Input data prod (position, attribute)-production data (the position and attribute of origin, destination and separate factors, current and predict data).

Output data traffic (position, attribute)- traffic data (the position and attributes of traffic stop (point) and network (line), more specifically): network flow $\hat{T}_{ij}$; total outflows from origin $\sum_{i=1}^{I}\hat{T}_{ij}$; destination inflow total $\sum_{j=1}^{J}\hat{T}_{ij}$.

Input specifications are number of origins, number of destinations, and name of data input file. There are four choices for the model type: unconstrained, production constrained, attraction constrained, and doubly constrained models. Four separation function choices include power function, exponential function, tanner function and generalized tanner function. Four estimation procedures are available: ordinary least square and weighted least square with odds ratio linearize procedure, and maximum likelihood by simulated annealing combined with a downhill simplex method. Fig. 3 shows the implementation of SIM.

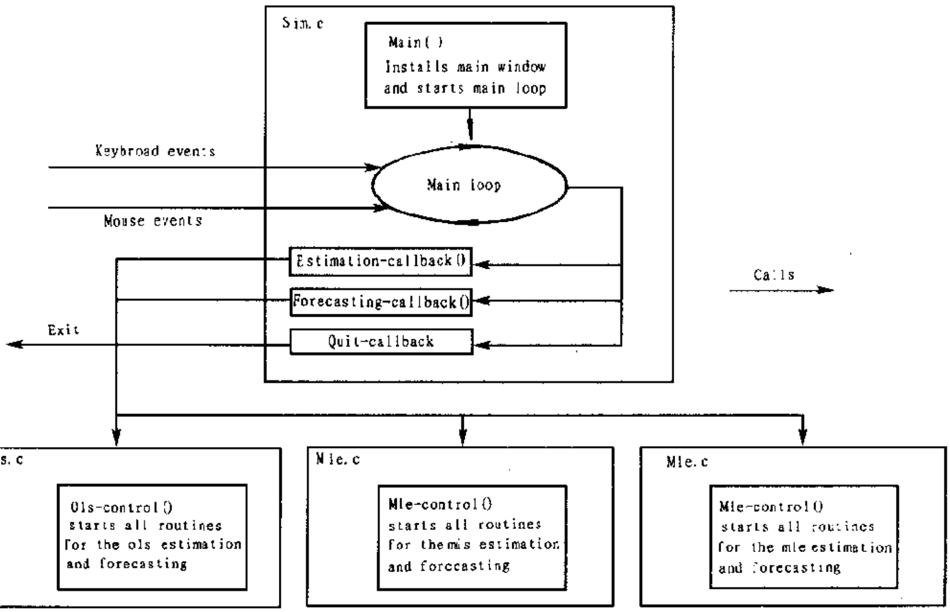

Fig. 3 A schematic overview of the implementation of SIM

4.2.3 I/O for the integrated urban traffic-environment model

Input data prod. (position, attribute)-production data (the position and attribute of origin, destination and separate factors, current and forecast data): V_i is the origin factor (block function, people, available, ...); W_j destination factor; F_{ij} traffic network.

Output data environ. (position, attribute)-environment data (the location and attribution of air pollution, noise, waste, crowd, and diseases): P_i is environment factors at points i; E_{ij} environment factors along roads from i to j.

5 Some applications

The integrated urban traffic-environment model can be used for different purposes.

5.1 Urban environment impact assessment

This is a forward simulation or forecasting by inputting production factors such as people density, GDP, salary of each block in a city, then a corresponding traffic spatial pattern is formed, and finally an environment impact pattern location and attribute can be disclosed.

5.2 Urban traffic management

The second use of the model is backward simulation by inputting environment limitation along the traffic network or water pollution control (Qian, 1998) and outputting traffic pattern acceptable in terms of environment regulations.

5.3 Urban sustainable development planning

The third use is for urban sustainable development planning by input traffic and environment variables respectively and correspondingly output environment and traffic consequences, iterating the process and the final reaching convergence and equilibrium solution that is the option for urban sustainable development.

5.4 Urban development decision-making

The forth use is for decision making support: by assuming a new regulation on urban environment, to estimate its impact on the traffic pattern, or by assuming a new regulation on traffic flow pattern and auto types or pollution penalty system (Zou, 1998), to assess its possible effect on urban environment, or by assuming a new urban land use planning and traffic network reform (Jin, 1998), to forecast its urban environment consequences.

6 Discussion and conclusions

Urban environment pattern depends heavily upon urban traffic pattern, the balance between traffic (implicit production) and environment leads to urban sustainable development. An integrated urban traffic-environment model makes it possible for planning and managing urban traffic and environment interactively.

The integrated urban traffic environment model consists of three components of urban production (population density, GDP, salary, etc. in blocks), urban traffic variables and urban environment variables; and two links between urban traffic planning variables and urban environment variables, and between SIM (spatial interaction model) and traffic planning variables.

The integrated model is opened and can be linked directly or indirectly to other subsystems in larger cycles (Hillier, 1998) such as global climate model (GCM), urban economic model, social effects, regional technique diffusion model, labor market model, integrated environmental assessment (IEA) (Murlis, 1998), chemical pollution and diseases (Xu, 1998; McCarthy, 1998), ecology (Wang, 1998), GPS, and so on.

By adopting computer virtue reality technique, the integrated urban traffic-environment model can be implemented with more artificially intelligent and friendly user-computer interaction.

References

Fischer M, Trapletti A, Wang J, 1996. SIM user's manual. A flexible toolbox for spatial interaction modeling. WSG-RR 6/96

Jin F, Yang Y, 1998. The development of high speed transport system in metropolitan area in China. Proceedings of Sino-British workshop on urban environmental enhancement and sustainable development. Beijing. 9

Hiller B, 1998. The common language of space: an integrated way of looking at the social, economic and environmental sustainability in cities. Proceedings of Sino-British workshop on urban environmental enhancement and sustainable development, Beijing. 1

Mackett R. 1998. Towards the solution of urban transportation problems in China. Proceedings of Sino-British workshop on urban environmental enhancement and sustainable development, Beijing. 5

McCarthy M, 1998. Sustainable urban development-the public health dimension. Proceedings of Sino-British workshop on urban environmental enhancement and sustainable development, Beijing. 27

Murlis J, 1998. Integrated environmental assessment: an urban perspective. Proceedings of Sino-British workshop on urban environmental enhancement and sustainable development, Beijing. 6

Qian Y, 1998. Strategic measures for water pollution control in urban area of China. Proceedings of Sino-British workshop on urban environmental enhancement and sustainable development, Beijing. 15

Wang R, 1998. Understanding the urban eco-complex and ecological engineering to meet the challenge of industrial transformation. Proceedings of Sino-British workshop on urban environmental enhancement and sustainable development, Beijing. 18

Xu X, Chu S, 1998. Chemical pollution and sustainable development. Proceedings of Sino-British workshop on urban environmental enhancement and sustainable development, Beijing. 12

Zou J, 1998. Urbanization, water stress, and policy reforms in China. Proceedings of Sino-British workshop on urban environmental enhancement and sustainable development, Beijing. 25