Urban Transportation Planning and Traffic Management in China

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As traffic congestion in Chinese cities worsens with the growing use of motor vehicles and the increasing conflicts between motorized and nonmotorized modes on the roads, economists, planners, and politicians throughout the country pay more attention to traffic management and transportation planning. It is noteworthy that although many alternatives have been suggested for expanding the transportation system and various measures have been investigated for discouraging bicycle use, very few of them have been put into practice. This testifies to the extreme difficulties of regulating nonmotorized transportation in China; the recommended plans might not be compatible with the financial resources of the community. The range of possible traffic management and transportation modeling techniques suitable for Chinese conditions is reviewed. These techniques mainly include land use and transportation planning, travel demand forecasting, signalized junction design, and area traffic control systems. The applicability of these techniques in China is discussed, and those currently used in Beijing and Shenzhen are summarized.

Good transportation planning by itself will not solve most of the urban congestion problems in China. Appropriate traffic management schemes will be required to harness the advantages of measures that offer the best solutions to the anticipated transportation problems while minimizing their adverse effects. Transportation planning methodologies and traffic management measures in developing countries differ from those in countries with the most advanced economies. It is therefore desirable to develop a basic list of development priorities based on transportation planning and traffic management techniques appropriate to different contexts in China. The essential parts of such a technique include the development of the following:

- Methods for devising alternative plans and development programs on the basis of an optimization analysis of land use and transportation systems.
- Simple methods of forecasting future travel demand, which should not require complex data bases and extensive surveys.
- Computer-aided design of signalized junctions and of area traffic control (ATCs) systems, particularly when experienced traffic engineers are scarce.
- Acceptable and effective measures that would alleviate the problems of heavy pedestrian flows and minimize the conflicts between bicycles and motorized vehicles.

Some of these techniques can possibly be adapted from existing procedures in Hong Kong, but caution must be given to the cultural and political differences between China and Hong Kong. Emphasis should be placed on encouraging simplicity, minimizing the manpower invested, and tailoring the efforts to the travel environment of China. This paper examines the range of possible transportation planning methodologies and traffic management techniques suitable for conditions in China. The applicability of these techniques to China is discussed.

First, the urban transportation problems and the planned solutions are briefly reviewed so as to give the background of the unique traffic characteristics in China. Two Chinese cities have been selected for discussion: Beijing and Shenzhen. Their locations are shown in Figure 1. This review is followed by investigations of different transportation planning and traffic management techniques appropriate for China, especially those with Hong Kong "connections." Finally, the techniques currently used in Beijing and Shenzhen are summarized.

BEIJING

Beijing is an ancient city that is more than 1,000 years old. It was the capital of many dynasties, including the Liao, Jin, Yuan, Ming, and Qing dynasties, up to the People's Republic of China.

The Beijing metropolis has a total area of 16 800 km^2. The city is divided into 19 districts, and the total population is more than 10 million. The population of the Beijing urban area is about 6.2 million; the urban area tapes up only 2700 km^2, and the built-up areas take up about 400 km^2.

Zheng has reviewed the transportation network in Beijing, in which the total length of roads in the Beijing urban area exceeds 3000 km and covers 27 million m^2 (*1*). The roads in the center alone account for 780 km in length, covering 6.9 million m^2. Figure 2 illustrates the main road system of Beijing, in which three road categories are classified, namely, main trunk routes (including axis routes, ring routes, through routes, and radial routes, for a total length of 640 km), secondary trunk routes (i.e., the main roads in the districts, for a total length of 490 km), and local roads in small districts (about 560 km). There are 40 grade-separated interchanges.

Beijing has a large population of bicycles, and pedestrians are extremely crowded on the streets. With the rapid increase in bicycle use and the continuous growth in vehicular traffic, it is necessary to separate pedestrians from vehicles and fast-moving vehicles from slow-moving bicycles. At present there are about 400,000 motor vehicles and 7 million bicycles in Beijing.

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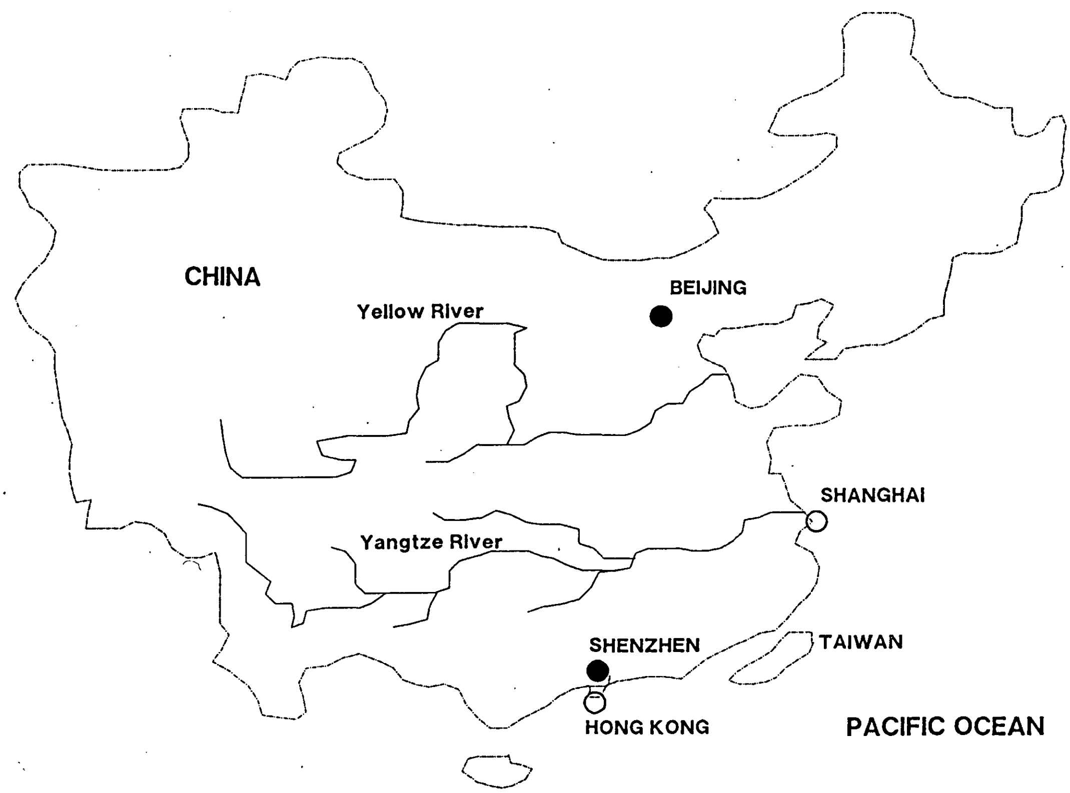

FIGURE 1 Locations of Beijing and Shenzhen.

By the end of 1991, there were two underground railway lines in the Beijing urban area; their total length is only 40 km. The first line is a straight line from Fuxingmen to Shijingshan. The second line is a circle line under the second Ring Road. The two lines carry more than 1 million passengers a day.

The long-term plan for the underground railway network of Beijing consists of eight lines. Three straight lines run from north to south. One line runs northwest, crosses the center of Beijing, and then runs to the northeast. One line runs from the southwest, crosses the center area, and then runs to the southeast. The final one is a circle line under the third Ring Road. According to the long-term plan, the total length of the Beijing underground railway will be 250 km. In view of the long-term planning in Beijing, a systematic planning approach would be required for determining the development strategy for the next decade.

Land Use and Transportation Planning

The newly developed areas of Beijing are more than 10 times the size of the old city district. With the continuous expansion in the developing areas, attention has been given to land use and transportation planning. In the middle of 1990, a team of planners and engineers from Beijing came to Hong Kong to learn the Land Use and Transport Optimization (LUTO) model that is being used for strategic planning in Hong Kong (*2*). The LUTO model is a computer analysis system that enables the simultaneous selection of land development areas and new transportation links by optimizing an objective function consisting of land development costs and transportation costs, as conceptualized in Figure 3.

However, the transportation planning process should be based on community development goals and objectives. The recommended plans must be compatible with the financial resources of the community. Taking these into account, the LUTO model has been applied to the developing areas in Beijing so as to determine the road and railway development programs and the preferred land use plans. Nine tasks have been completed for setting up Beijing's LUTO model:

1. Analyze past trends of investment in the development of Beijing and identify the likely investment from now to 2010.
2. Collate and review all development plans and proposals, including all committed major development works and potential new links.
3. Derive additional population in Beijing to be rehoused by 2010 and set up a land cost model.
4. Collate socioeconomic data required for calibration of and forecasting with the travel demand model.
5. Calibrate the travel demand model and build the transportation networks such as road, bike, public transit, and rail networks.
6. Set up the maximum networks and infer the likely transportation management policy (control of bikes, truck routes, and public transit fares).
7. Develop a cost model of the potential new roads and the proposed railway lines.

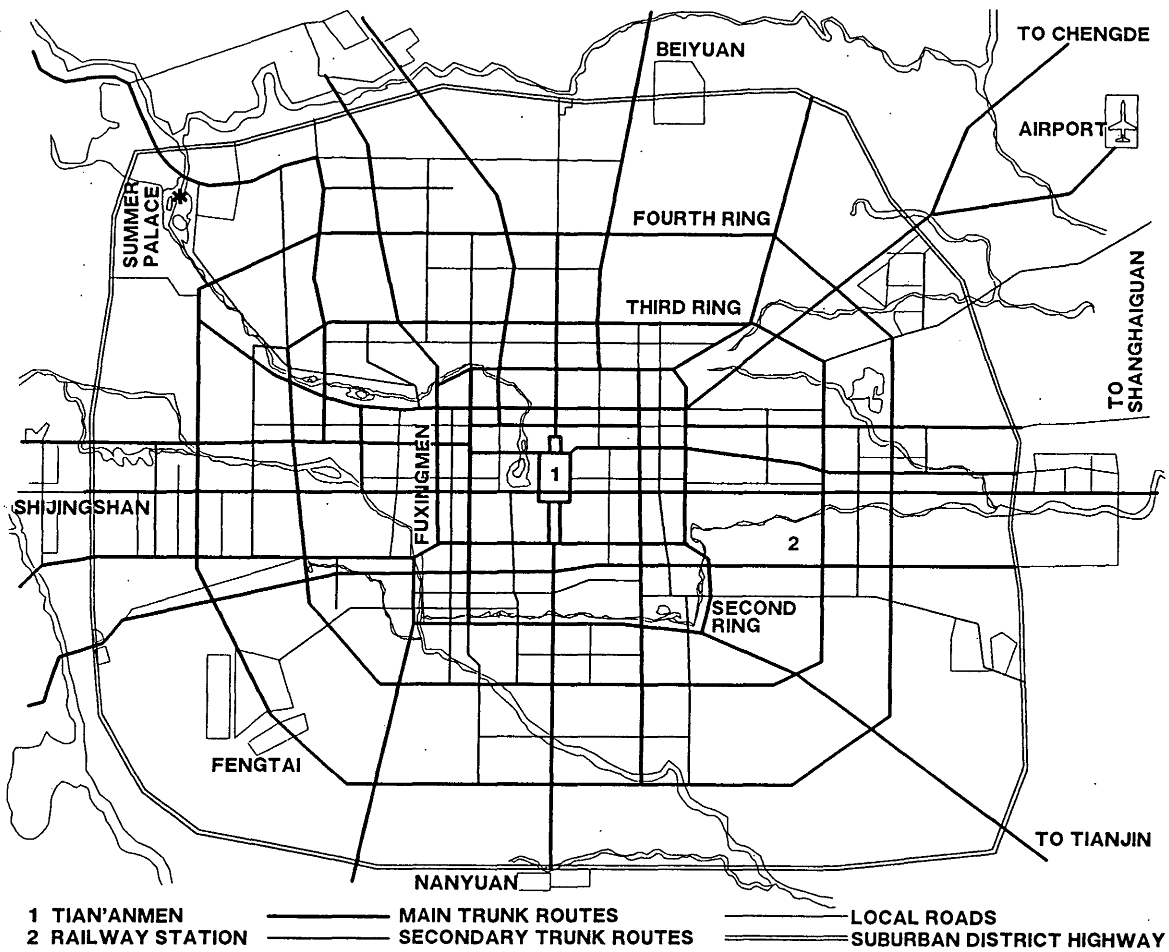

FIGURE 2 Road system of Beijing.

8. Review planning objectives of recent studies and recommend objective functions to be used in the LUTO model.
9. Install the LUTO model on a personal computer and test the programs.

A practical optimization model for the integrated land use and transportation planning has been developed in Beijing; it considers various development objectives and financial constraints of the community. Its application to the long-term planning in Beijing has shown the existence of significant common components in the alternative growth patterns that optimize the usual quantitative planning goals. Thus, a systematic approach for strategic planning becomes possible, whereby the development strategy would be built of the common components of the alternative LUTO-derived patterns.

Traffic Management Measures

To solve the growing traffic problems in Beijing, the government has continuously expanded the road system. Apart from this, making good use of existing roads leads to efficient traffic management measures in solving Beijing's road congestion. In recent years, the following measures have been adopted:

1. Control the increase in vehicles according to plan and proportion. A "passing certification" is used to prohibit about 32 percent of the goods vehicles from entering the city during the day. Large amounts of goods that have fixed loading and unloading locations may be transported into the city only at night.
2. Give traffic management priority to buses in order to reduce the pressure on the arterial roads and to ensure the efficiency of the bus operation.
3. Promote transit services as one of the effective measures to attract more passengers and limit the increase in bicycles on the road. The transit system is being improved and expanded; transit transfer centers are being introduced so that passengers who have arrived by different modes can be collected and then effectively distributed over the transit lines expected [see paper by Wei and Ren (*3*)].

There are 39 and 53 signalized intersections in the east and center of Beijing, respectively, which have been controlled automatically by the ATC computer. Compared with the past, the delay for motor vehicles decreased 24 percent and that for bicycles, 15 percent; the capacity of intersections increased 20 percent. By the end of 1992, 250 intersections within the third Ring Road will also be equipped with signal controllers connected to the ATC computer.

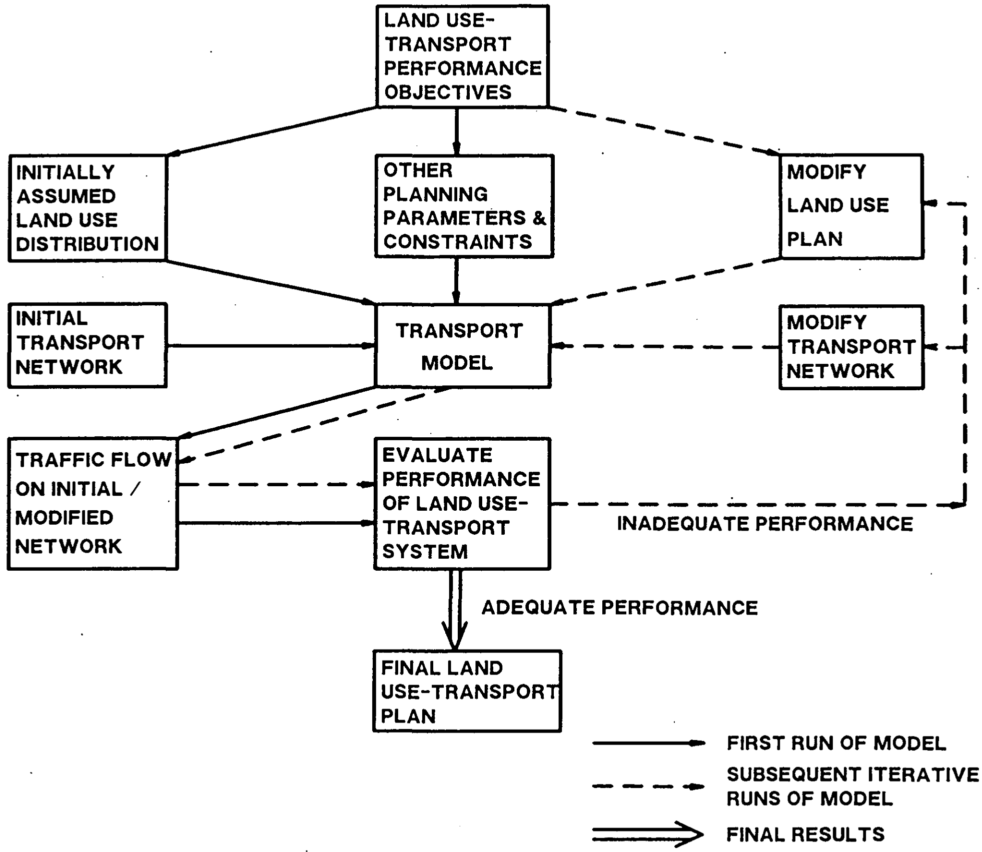

FIGURE 3 Conceptual outline of land use and transportation optimization process.

Moreover, traffic peak times are being staggered. On the basis of studies of passenger concentrations, the working hours for more than 220,000 staff from more than 450 companies can be staggered. This would somewhat help the rush-hour traffic problem.

SHENZHEN

Shenzhen is one of the special economic zones in China; it is just adjacent to the border of Hong Kong. The whole area of the city is 32.6 km^2; the registered population is more than 640,000, and the temporary or transient population is about 300,000. Local highway construction has proceeded quickly: 117 roads account for more than 420 km being completed. There are more than 45,000 motor vehicles and 300,000 bicycles in this city. Because Shenzhen has undergone rapid population growth and economic expansion since 1979, traffic problems have arisen especially in the urban area.

The traffic problems of Shenzhen can be portrayed as crowding, blocking, and noise. In the urban area, a shortage of public transit facilities is obvious: there are only 4.3 buses per 10,000 residents (compared to 8.9 in Beijing and 8.6 in Shanghai). Too many bicycles, particularly at road intersections, is one of the immediate causes of the various traffic problems at junctions.

At present, the local government still continues in land use planning and transportation network improvement. The distribution of commercial centers has been readjusted, and some major trunk routes have been upgraded. Grade-separated interchanges are being constructed, and a light rail transit line is also proposed to connect to the new Huangshi International Airport. Public transit is being improved to attract more passengers and to limit the number of bicycles on the roads.

After investigating measures to alleviate these traffic problems over the past decade, the Traffic Engineering Science Institute of Shenzhen (TIS) has obtained some valuable results, namely, an efficient data collection framework, simplified travel demand methods, a computer-aided design for isolated signalized junction, and an ATC system.

Efficient Data Collection Framework

The origin-destination (O-D) matrix is a spatially disaggregated measure of the quantity of travel within a defined study area. It is based on a zonal decomposition of the study area and simply expresses the quantity of travel between any pair of zones in the form of a matrix. Insofar as it can express travel demand, the O-D matrix is a fundamental input for most problems with planning and management of transportation systems.

Nowadays, a roadside interview survey is one of the commonly used methods in China to estimate the O-D matrix and to collect the relevant traffic information because it is more flexible and less labor-intensive. However, attention must be given to the selection of roadside interview stations, sample selection of vehicles, and design of questionnaires. Most of the problems arising from the use of the roadside interview survey are related to the procedure of expansion of survey data. This is because trips may pass through more than one survey station, so some trips may be sampled more than once. If the survey data from different stations are added without proper adjustment, the long-distance trips will be overrepresented.

The TIS, through a joint research project with the Civil and Structural Engineering Department of Hong Kong Polytechnic, conducted a comprehensive roadside interview survey in Shenzhen; it has served as a basis for testing the simplified travel demand model. The objectives of the survey were to determine (a) the origins and destinations of motorized trips generated in Shenzhen, and (b) the choice of routes of motorists traveling within and through the urban areas of Shenzhen.

The survey was carried out over two 2-hr peak periods (9:00 to 11:00 a.m. and 3:00 to 5:00 p.m.) from December 15, 1987 (Tuesday), to December 17, 1987 (Thursday) because most peak-hour trips in Shenzhen are made by company cars for business or commercial purposes. Forty-four stations were selected for roadside interviews. A synthetic network of 23 zones and 328 links was adopted. Figure 4 shows the study area and the interview stations.

In the study, a methodology for estimating an O-D trip matrix from roadside interview surveys was formulated, and a framework for processing roadside interview data relating to trips crossing multiple screenlines was suggested and shown to be practical and useful; see Lam et al. (*4*). In the survey, collecting O-D and route information by tracing the exact path taken on street map, with the assistance of field surveyors, was an effective and reliable way to determine O-D matrix and link choice proportions.

There were 13,330 motorists surveyed and 13,250 valid questionnaires for subsequent data processing. Out of a total of $2 \times 23 \times 23 = 1{,}058$ estimates for both a.m. and p.m. peak O-D matrices, only 14 of them have variances greater than 1,000 (standard error = 32 trips). For these 14 estimates, the average of their coefficients of variation is only 0.1386, indicating that the estimates are quite reliable and accurate as far as sampling errors are concerned.

Simplified Travel Demand Methods

Estimating an O-D matrix directly from traffic counts offers great economic advantages because it eliminates expensive surveys, burdensome data editing, and subsequent analysis. Because link flows are relatively inexpensive to obtain and are regularly collected for various purposes (e.g., ATC system

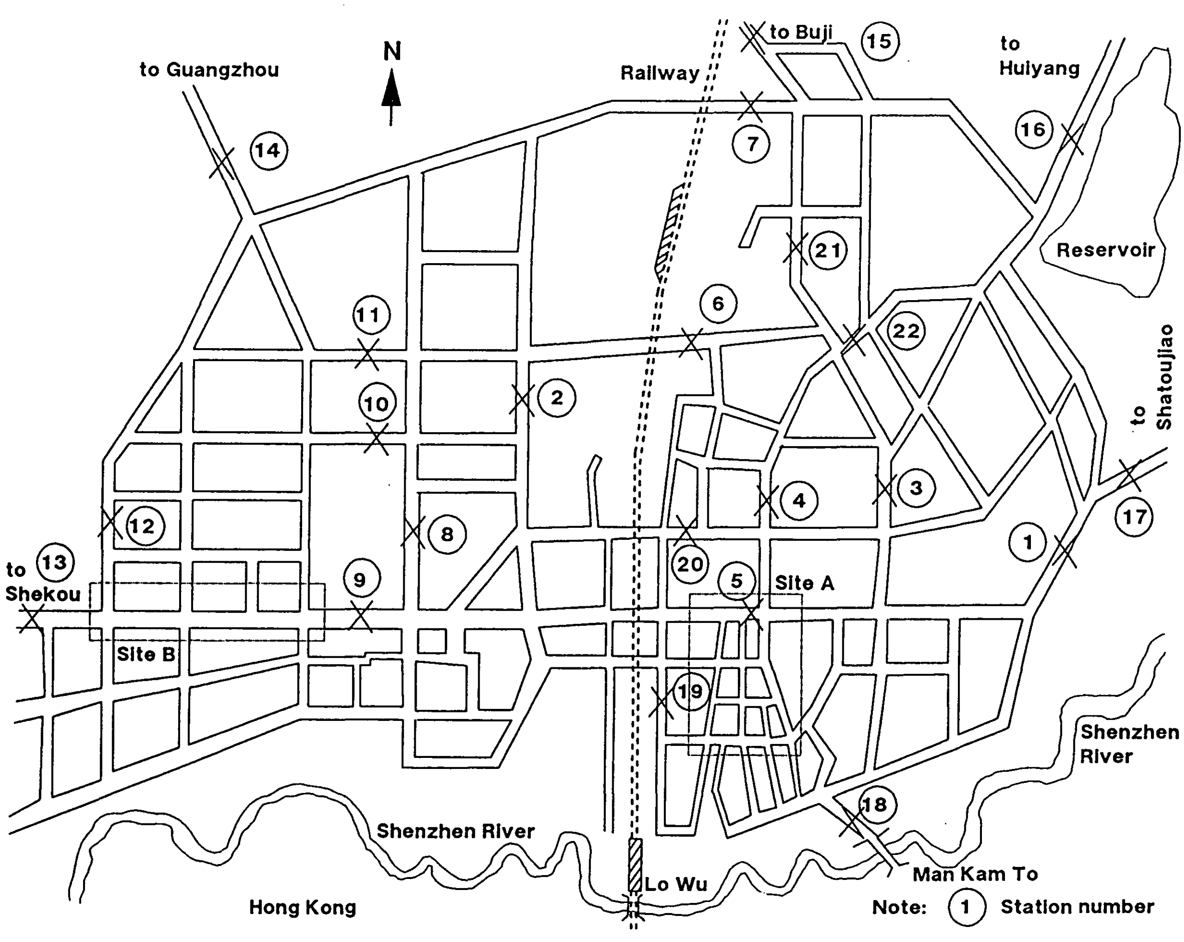

FIGURE 4 Locations of roadside interviews in Shenzhen.

and accident studies), and because the automation of traffic counts has been introduced in most of economic centers in China, the possible application of such an O-D estimation model is attractive. This method is suitable for the design and evaluation of traffic management schemes.

The model derived by entropy maximization (EM) is one of the O-D matrix estimation techniques commonly used in developed countries. Examples of various applications have been given in papers by Hall et al. (*5*) and Beagan and Bromage (*6*). However, the accuracy of the EM model in developing countries has not yet been well defined.

Lam and Lo have examined how data information affects the EM model performance and estimated the effects of information variability on model accuracy (*7*). Empirical results from Shenzhen indicate that the use of a better prior estimate of the trip matrix can dominate the EM model accuracy, especially when the link-flow information is limited. If no prior information is available, then the increasing number of links with flow information would improve the O-D estimation effectively. Moreover, the better the link choice information, the further reduction in the prediction error is found. It is concluded that the EM model would be useful for short-term planning when there is no significant change in the network.

However, for long-term planning, a combined trip distribution-assignment model for multiple user classes that was introduced by Lam and Huang would be appropriate to be used in China because the model can also be calibrated by traffic counts only (*8*).

Computer-Aided Signal Design

The designs of lane uses and stages for signal controls at isolated junctions are usually undertaken by experienced traffic engineers. The development of computer software for the designs of lane uses and stage sequence is valuable in developing countries, especially in places where there are only a few experienced traffic engineers. Much research on designing signal stages and timings has been conducted, but very little has been done for the optimal design of lane uses or lane configurations at junction approaches. Lam et al. have developed an integrated model for both lane use and signal stage designs; this model can maximize the capacity of an isolated signalized junction and coordinate the signal plan of individual junction for ATC in Shenzhen's road network (*9*). It is found that integrated design performs better than optimal stage design where a suboptimal or poor lane-use configuration is fixed in the latter.

Integrated Design of Lane Uses and Signal Stages

In the preceding study, a mixed-integer linear programming model for the integrated design of lane use and signal stage has been suggested and shown to be practical and useful in China, where experienced traffic engineers are scarce. The linking of the individual signal plan to the ATC system is also conducted with some fine-tuning improvements in the computer program (TRANSYT-7F) for minimizing the overall delays, stops, and fuel consumption.

The performance of traffic signal control plans can be measured by a number of indexes, namely, *Y*-value (i.e., flow factor) among the selected junctions, number of traffic movements having a high degree of saturation, average vehicular delay, total uniform stops, total fuel consumption, speed, and performance index. The results of the evaluation tests on two selected sites in Shenzhen (see Figure 4), with respect to these measurement indexes, indicate that the integrated design of the lane use and signal stage can minimize the *Y*-values but maximize the ultimate reserved capacities of the road junctions. In comparison with the existing signal plan in Site A, the integrated design performs better in terms of all the measurement indexes. In Site B, the integrated design does not outperform the expert's manual design in all measurements of system efficiency. However, it can produce results that are at least comparable to those designed by experienced traffic engineers. Moreover, manual design depends much on the designer's experience; hence, junction conflicts may sometimes be overlooked whereas integrated design has all kinds of conflicts as built-in constraints.

There is indication that both integrated and expert's manual designs make use of all-red for pedestrian phase. This is because the junctions in Shenzhen are generally wide, so patching pedestrian movements with traffic movements may not be advantageous.

Application of ATC in China

ATC is the centralized control of traffic signals on an areawide basis by means of computer. Usually the traffic signal controllers on street are linked to the central computer in the control center by data transmission cables. The degrees of sophistication of an ATC system vary from the fixed time plans (developed by TRANSYT) based on available traffic data to the fully responsive system calculated on-line (by SCOOT or SCAT).

Although the TRANSYT family of programs continues to be one of the most widely used computer programs in the world for ATC, improvements are still required for modeling local traffic conditions in different countries. Willumsen and Coeymans (*10*) studied the effects of the TRANSYT applications in Santiago, Chile, and discussed special research undertaken to model traffic conditions in developing countries.

The TRANSYT program has been used to develop signal timing plans in Hong Kong since 1977. In China its application is relatively new, although SCOOT and SCAT are being used in Beijing and Shanghai, respectively. Wong has discussed the process and results of developing signal timing plans using TRANSYT-7F in Shenzhen (*11*). As a result of model calibration, a platoon dispersion factor of 0.45 was found most appropriate for all time periods. Both the model and the field results indicated improvements in total travel time, total delay, number of stops, and average speed; thus, TRANSYT-7F is an available tool in developing signal timing for Chinese cities.

CONCLUSION

In summary, it is clear that rather than indiscriminately importing technologies that are relatively successful in more advanced countries, China has committed itself to identifying ways to maximize the effectiveness of transportation planning and traffic management interventions. In some cases, this can be achieved by adapting transportation methodologies used in Hong Kong. However, it should be emphasized that variations and adjustments are required to reflect the unique nature of the transportation system in China. Traffic solutions must be specific to the culture and to the individual case. A summary of those techniques for Chinese conditions follows.

First, the Hong Kong LUTO model is being used for strategic planning in Beijing, taking into account the cultural and political differences between China and Hong Kong. It is a tool for identifying the essential decisions that need to be made on the land use strategy so that maximum flexibility can be achieved. This point is particularly important in Beijing's planning in view of the rapidly changing planning environment.

Second, a major problem often faced in China is the lack of data. An efficient data collection framework and simplified travel forecasting method have been developed for Shenzhen and are generally applicable to the situations in China.

Third, with the unique characteristics of road users and traffic composition, such as the huge number of cyclists and the mixture of the high- and low-speed vehicles on the road, the traffic parameters in Chinese cities are very different from those in other parts of the world. With reference to the latest application of computer technology and methods for automating ATC systems, a suitable computer-aided signal design method applicable to Shenzhen's traffic conditions has been developed and should be valuable in developing countries, especially where experienced traffic engineers are limited.

Fourth, there has been a strong growth of the licensed vehicle fleet in most of the economic centers of China. To alleviate the growing congestion, the government pointed out that the old cities should be redesigned and at the same time ATC systems and various traffic restraint measures should be implemented so that the serious traffic problems can be solved.

Finally, to minimize the conflicts between bicycles and other motorized vehicles in large cities of China, separated facilities are being introduced and effective traffic management measures have been applied. More important, public transit should be improved to attract more passengers and to decrease the number of bicyclists on the streets.

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