Traffic Modeling Techniques for the Developing World: Case Studies

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Traffic models have been used for transportation planning in the Western World for more than 30 years. Recently, attempts have been made to adapt these techniques, which generally originated in developed countries, to suit the needs of the developing world. In adapting the original models, it has usually been necessary to change them, sometimes considerably. The reasons why Western-type traffic models may not be applicable to the developing world are examined. Case studies of rural and urban environments in the Yemen Arab Republic, Sudan, Qatar, and Oman are used as examples, and suggestions are made for changing the Western-type models to better suit developing nations.

Traffic models have been used for transport planning in the Western World for more than 30 years. During the past 15 years or so, attempts have been made to adapt these techniques, which generally originated in developed countries, to suit the needs of the developing world (*1–5*).

In adapting the original models, it has often been found necessary to develop new formulations for the models or to change the explanatory variables that they employ. There are doubtlessly many reasons why Western-type traffic models have not been found applicable in the developing country environment, but some of the major ones are as follows:

- It is difficult to obtain the required statistical data.
- By definition, less-developed countries start from a low base, and growth is therefore often much more rapid.
- Because world conditions have changed considerably since developed countries were in a similar transport position, today's developing countries are unlikely to follow the same growth pattern as the developed world.
- Ethnic, political, and environmental differences produce different transport needs and behavior characteristics.

In view of these factors, it has generally been found necessary to tailor existing Western technology to suit individual conditions in each developing country. This is not to say that the Western technology has no validity for such countries but simply that this validity must be established rather than assumed for each individual situation.

BACKGROUND STATISTICAL REFERENCE

It is perhaps desirable to start by giving a global numerical dimension to the Third World transport problem. Since 1950, the world's population has more than doubled, from 2.5 billion to over 5.0 billion. The population increase has been faster where income is low and has been concentrated in developing countries. Of the 1986 world population increase of some 80 million plus, more than 70 million is estimated to have been in developing countries. These nations now contain over three-quarters of the global population.

At present, the population growth rate in developing countries averages some 3 percent per year. This implies that, unchecked, the population of these countries would more than quadruple in the next 50 years. Even if couples in these countries have fewer children, there is still a certain population momentum due to the "baby bulge." This phenomenon is the result of high fertility and falling mortality some 20 years ago. The offspring of the baby bulge have now reached child-bearing age. Therefore, to use World Bank estimates (*6*), the world population will continue to rise at 80 million per year for some years to come.

This rapid population growth has also been associated with rapid urban expansion, which causes associated economic and social problems in the developing world. Between 1950 and 1980 the number of urban dwellers in developing countries has been growing at a rate of some 4.1 percent a year. By the year 2000, Mexico City will probably be the world's largest city, followed by Brazil's São Paulo. In 1950, São Paulo was smaller than Manchester, England; Detroit, Michigan; or Naples, Italy. London, the world's largest city at the beginning of the 20th century, will not be ranked in the 25 largest cities at the end of the century.

In 1982, there were 684 vehicles per 1,000 people in the United States, whereas the same figures in Great Britain, Chile, and Jordan were 320, 75, and 63, respectively. In the United States in 1984 the automobile population increased from 126.15 million to 127.87 million, or by less than 1 percent, whereas in Venezuela in the same period the automobile fleet increased from 1.96 million to 2.12 million, or by over 8 percent. In South Korea, the automobile fleet increased from 0.38 million to 0.46 million, representing a staggering annual increase of 22 percent (*7*).

These rates of growth in urbanization and the accompanying demand for transport and transport infrastructure that have been and are being experienced in the developing world far exceed those that have been experienced in the developed world. Also, when projected forward, these rates take us into ranges (such as the 20-million-person city) previously unknown. This poses a double dilemma for those responsible for preparing plans and designs to accommodate such growth. First, the explosion in growth implies that historic records cannot be used to project the future; second, when

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projections are made for the future, the magnitude of the problem is beyond all experience elsewhere in the world.

DESCRIPTIONS OF TYPICAL PROBLEMS

Described in this paper are some examples of recent Third World transport studies in which the author was involved and in which the standard traffic modeling approach needed to be adapted. The problems tend to differ for urban- and rural-type studies, and two typical examples of each case are cited in the paper.

Rural Studies

In the environment of the developing country, certain factors dictate several typical differences of approach. First, many of these nations have primitive track road systems that generally have not been engineered and that are poorly indicated on existing plans. These tracks often provide a multiplicity of routes that are impossible to identify or survey over a wide area. Second, these nations may have embryonic main road networks, which means that many existing journeys are made on primitive roads with very low average running speeds and considerable journey inconvenience. Extending the main road system in such cases may dramatically change accessibilities and lead to major changes in trip distribution and very high levels of traffic generation. Finally, there may be delayed road network development, in which high levels of latent demand for transport have built up. Original networks, often built to suit colonial needs, do not match existing population distributions and present economic activities.

Urban Studies

The urban environment in the developing world is often considerably different from that of larger western towns and cities. In particular, developing urban situations generally (a) are growing much faster than Western cities, (b) have mixed ethnic compositions of widely variant socioeconomic composition, and (c) have narrow street central cores constructed prior to the age of mechanized transport.

RURAL STUDY EXAMPLES

The Yemen Arab Republic Highway Master Plan

Background

To understand the nature of the problem of producing a national traffic model for the Yemen Arab Republic (YAR), it is necessary to understand the existing population distribution characteristics and the stage of development of the highway network of the country. The population is very widely dispersed in small settlements, as indicated in Table 1.

People in small settlements (i.e., the bulk of the population) are generally served by very minor tracks. These tracks are often of a very low standard and are only passable (with difficulty) by jeep-type vehicles. This network was estimated to comprise about 30 000 km. The existing paved network comprised some 2 000 km, together with about 1 000 km of gravel roads. The test network for the highway master plan (*8*) was therefore defined by function, rather than by existing traffic demand, and roads down to the interdistrict level were considered. The administrative hierarchy consisted of the nation, 11 governorates, 171 districts, and about 50,000 villages. Each district had a nominated district center (local administrative center). The test network connected all district centers to the existing paved network.

TABLE 1 YAR POPULATION DISTRIBUTION

Size of Settlement	No. of Settlements	Percentage of YAR Total Population
100,000+	3	8.2
25,000–99,999	2	1.2
10,000–24,999	10	2.0
5,000–4,999	15	1.7
1,000–4,999	406	10.0
500–999	1,300	15.2
250–499	4,600	12.6
Under 250	46,400	49.1
Total	52,736	100.0

The problem was to estimate the probable transport demand on each link of the test network at various future times. Even for the existing situation, the true traffic volumes for all movements could not be surveyed. The tracks form a complex network, and often several alternative routes exist. However, the paved and gravel road system was clearly defined, and for this, accurate traffic movement information could be collected by origin-destination interview surveys.

The Master Plan was required to take account of the future changes that were proposed for the economy. The main components of these changes concerned increases in agriculture, industrial activity, exploitation of minerals, and formal employment.

Traffic Model Requirements

Given the instability of previous traffic trends and the major changes to the economy expected in the future, an analytical but robust analysis was called for. The model would need to reflect both present and projected transport demand for the major population centers and for the rural areas. A large number of schemes and network combinations would need to be tested, and an optimum staging for construction would need to be developed. Therefore a matrix method (representing origin-to-destination movements) was applicable. This method would then permit any test network to be developed and analyzed.

For the purposes of constructing the matrices, the country was divided into 78 zones with two external areas—Saudi Arabia and the People's Democratic Republic of Yemen (PDRY). The zones were selected to be relatively homogeneous in terms of population, terrain type, economic activity, and so on, and to follow existing administrative boundaries. The zones were numbered roughly in order of decreasing population density, so that the large cities and towns on the existing paved network had the lowest numbers. This led to a situation that may be represented graphically as shown in Figure 1.

This situation is not uncommon in transport planning. It is often referred to as the "Top-L" problem, and the matrix is referred to as a partially observed matrix. Partial matrix problems are well known and are often the normal situation in an origin-destination study. Methods for dealing with the classical problem (the partial matrix) have been well researched and are well documented (*9*). However, the problem here is somewhat different from the classic case.

In the case of YAR, the part of the matrix that cannot be well observed represents the bulk of the whole matrix. Also, it represents the bulk of the population, because 76.9 percent live in settlements of less than 5,000 inhabitants. Furthermore, the characteristics of these rural dwellers are quite different from those of the well-observed urban dwellers. However, it would be wrong to presuppose that vehicle ownership and motorized trip rates would be negligible in these small settlements. Early investigations indicated that rural vehicle ownership could be as high as, and in a few cases was higher than, that typically found in the towns. Rural trip rates were also established as not being inconsequential, but trip length distribution had no comparison with urban observations.

These requirements indicated that the problem could not be satisfactorily solved by standard techniques. The problem was such that each zone-to-zone movement (matrix "cell") would need to be modeled specifically. The modeling would need to be based not only on parameters that described each zone but also on the accessibility (time and cost) between each zone pair. The parameters that were available for testing to describe each zone, calculated for the base year and plan horizon years, were as follows:

Gross domestic product, (GDP),
Gross national product (GNP),
Income from government employment,
Income from industrial employment,
Income from agriculture and fisheries,
Agricultural production,
Agricultural consumption,
Industrial production,
Industrial consumption,
Trade out,
Trade in,
Percentage of households owning a vehicle,
Population, and
Population density.

Model Formation

A log-linear direct demand model of trip generation and distribution was selected for the study. This kind of model would be capable of representing the considerable growth of traffic expected to occur in YAR when substantial development of the paved road network is made. Such a model has far fewer parameters than the conventional doubly balanced gravity model and so is more appropriate when the observed trip matrix is rather sparse. Also, in the case of YAR, only six rows and columns could be fully observed and therefore available for a trip end model, whereas it could be shown that 3,676 cells (out of a possible 6,084 internal cells) had been fully observed and were available for the direct demand model fitting. The difficulty for a doubly balanced gravity model lies in the production of trip generation and attraction models that adequately reflect future travel time changes.

A log-linear direct demand model (*10*) makes the logarithm of the number of trips from zone i to zone j (T_{ij}) a linear function of the available explanatory variables. Specifically, for one of the models selected (out of some 40 models tested, employing different parameters),

$$\begin{aligned} \ln T_{ij} = 11.3 &- .00872\, d_{ij} - 1.81 \ln d_{ij} \\ &+ .244 (\ln E_i + \ln E_j) \\ &+ .854 (\ln G_i + \ln G_j) \\ &- .782 (\ln H_i + \ln H_j) \\ &- .0238 (\ln P_i + \ln P_j) \end{aligned}$$

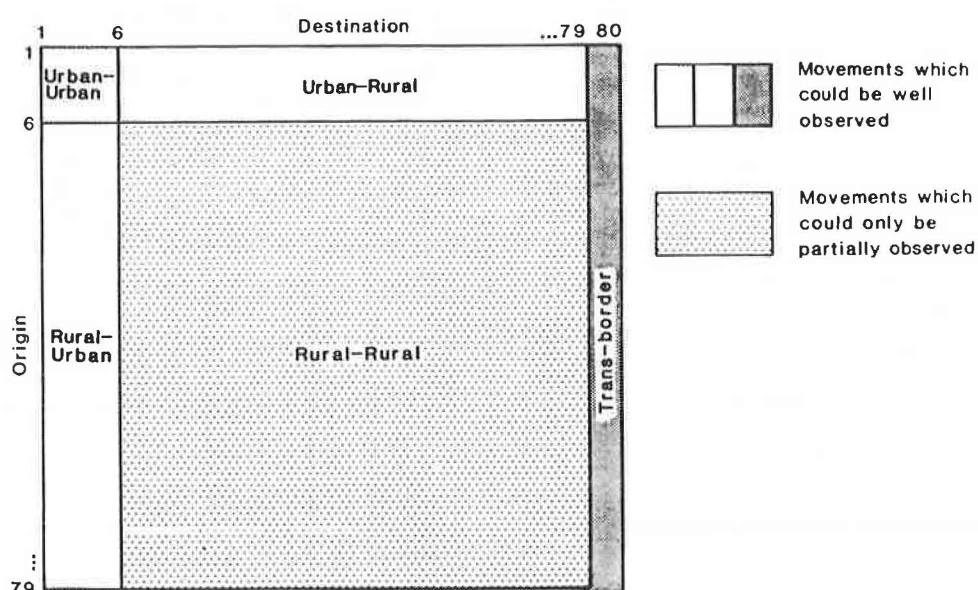

FIGURE 1 Matrix of origin-to-destination movements for YAR.

or equally,

$$T_{ij} = E_i^{.244} G_i^{.854} H_i^{-.782} P_i^{-.0238} \times E_j^{.244} G_j^{.854} H_j^{-.782} P_j^{-.0238} \times \exp(11.3 - .00872\, d_{ij} - 1.81 \ln d_{ij})$$

where

d_{ij}	=	travel time from zone i to zone j;
E_i, E_j	=	population of zone i, j;
G_i, G_j	=	income from government of zone i, j;
H_i, H_j	=	GDP of zone i, j; and
P_i, P_j	=	population density of zone i, j.

The model directly predicts the number of trips in a cell, given the fitted coefficients and explanatory variables for the cell. From its second written form, the model value can be seen to be a product of an origin zone factor, a destination zone factor, and a travel time factor, and each factor itself is of product form.

The model may use any transformations of the available explanatory variables. For the selected model, it was found that only travel time deserved a more complicated treatment than merely the logarithm. It was also discovered that the coefficients of corresponding origin and destination zone variables could be made equal with no worsening of the fit.

The direct demand models were fitted by choosing the coefficients to minimize

$$\Phi = 2 \sum_{ij} (T_{ij} - N_{ij} \ln T_{ij} - N_{ij} \ln N_{ij})$$

where T_{ij} is the grossed-up model value, N_{ij} the grossed-up observed value, and the sum is taken over all observed cells. A cell contributes to Φ an amount that increases as T_{ij} differs from N_{ij}. For T_{ij} close to N_{ij}, this contribution is close to T_{ij} $(N_{ij}/T_{ij} - 1)^2$, a squared relative error weighted by T_{ij}. Thus, $(\Phi/N_{++})^{1/2}$, where N_{++} is the total number of observed trips, is a weighted root mean square relative error.

The effect of using this fitting criterion is that if Y_{ij} is any one of the explanatory variables, the coefficients will be chosen so that

$$\sum_{ij} T_{ij} Y_{ij} = \sum_{ij} N_{ij} Y_{ij}$$

exactly. This fitting measure was chosen because it is the one usually used in doubly balanced gravity model fitting and because as long as a constant and the travel time are included in the model, it ensures that the model values of total trips and total trips multiplied by travel time equal the corresponding observed values.

An alternative fitting criterion is maximum likelihood. The observed trip numbers can very reasonably be described as scaled-up Poisson samples, and maximum likelihood fitting is obtained by weighting each cell's contribution to Φ by the effective sampling fraction for the cell (the reciprocal of the index of dispersion). This changes the fit from one in grossed-up trip numbers to one in trip counts. The two criteria are the same if the sampling fraction is the same for every cell. Maximum likelihood fitting does not ensure that total grossed-up trips and total travel time are the same for model and observed. When this method was used in a trial fit, it led to a 30 percent error in total trips, which was felt to be unacceptable. It should be noted that the sampling fractions vary by a factor of 10; some cells were highly sampled because of multiple interceptions.

Aims of Model Selection

A great many log-linear models may be determined from a given number of explanatory variables and their transformations. Five rules for helping select a final model are as follows:

- It should fit the data well;
- It should have a sensible interpretation;
- It must be suitable for forecasting;
- The coefficients should not be large; and
- Coefficients of retained variables should be larger than their standard errors of estimate.

The second rule means that variables that would be expected to increase the number of trips should have a positive coefficient. When the model is used for forecasting, it is likely that some of the variables will have larger values than those that occur in the base year data. This applies to population and the economic variables but not to travel time.

The third rule says that the model must behave reasonably when this occurs. The forecast variables will have some error. Because the variance of the linear part of the model will be the sum over the variables of their forecasting variance times the square of their coefficient, large coefficients tend to mean large forecast variance. In particular, the fourth rule means avoiding variables in the model that are similar and have large coefficients of opposite signs.

When these rules were followed, the last two turned out to be automatically satisfied. The "suitable for forecasting" rule had a major effect.

The Khartoum–Wad Medani Corridor (Sudan) Example

Background

This study involved several levels of traffic investigation, from consideration of transport movements by all modes in the northeast of Sudan through to the study area region and thence to the corridor itself (*11*). The aspect described here relates to the final level of investigation in which a comparison was made of the options of doubling the existing paved road on the west bank of the Blue Nile or building a new paved road on the east bank.

In passing it may be noted, however, that for the whole area study, a considerably better model fit was obtained by using a direct demand model (as described for YAR) than was obtained with a doubly constrained gravity model. The explanation of this lay in the fact that Khartoum and Port Sudan exhibited entirely different traffic characteristics from the rest of the country and thus could be modeled separately with the direct demand formulation.

The Khartoum–Wad Medani Corridor example is similar to the YAR case in that one of the problems was to estimate future traffic volumes in a situation where interzonal travel times would be considerably altered by the construction of the new paved East Bank road to be studied. However, the situation differs from YAR in that the "with scheme" scenario could be inferred from other available data.

Approach

To assist in the quantification of the likely magnitude of generated traffic, an analysis was made of the trip rates by trip purpose, which were established by the consultants' roadside and home interview surveys. For this exercise, zones on the west bank of the Blue Nile and zones on the east bank were examined separately. Zones close to the west bank have generally good accessibility provided by the existing paved road, whereas zones close to the east bank have generally poor accessibility. However, the socioeconomic surveys indicated that households on both sides of the Nile were quite homogeneous in terms of their characteristics.

The analysis indicated, for example, that on average, one trip was made per day to Khartoum or Wad Medani for every 407 people living within a zone on the west bank. For the east bank the corresponding figure was one trip per day for every 842 people, or less than half the trip rate on the west bank. Other zone-to-zone movements were also examined for west and east bank zones, and a similar relationship was found.

If the explanation of the difference in trip rates between the west and east bank zones may be attributed purely to the relative difference in accessibility, which is entirely plausible, then an estimate may be made of the level of generated traffic that would occur if accessibility were equal on both sides of the Blue Nile. Thus, if a paved road also existed on the east bank of the Blue Nile, one might expect existing person trips (i.e., nongoods trips) to more than double. Of course, such a change in trip-making behavior could not be expected to occur instantly. However, it is likely that over a period of time, if equal accessibility occurred on both banks, then trip rates would also stabilize and become equal on both sides of the Blue Nile.

Summary of Rural Study Problems in Developing Countries

Trip distribution, traffic generation, and traffic growth rates generally require special treatment in rural traffic studies for developing countries. Sometimes these problems may be tackled by adapting the formulation of the traffic model. In this respect a direct demand formulation that combines trip generation and attraction with trip distribution in one process can be more successful than the two-stage trip end and doubly constrained gravity model approach. In other cases, trip rates and trip distributions may be transported from a "with project" analogous case in the country in question to appraise a "without project" case at another location. If this "transportation" of behavior from one location to another is to be attempted, control socioeconomic household data (usually from household interviews) will be needed.

Elasticities between supply and demand are often much greater (a value of 20 is not unthinkable) in the developing world than those established in Western studies. However, the range of values between different locations is also considerable, and a suitable figure generally needs to be established for each individual case.

URBAN STUDY EXAMPLES

The Doha Capital Area (Qatar) Study Example

Background

As part of a national traffic study, an urban traffic model was created for Doha, the capital of Qatar. The modeling approach followed classical methods and included home interviews and roadside traffic interviews, as well as a large number of time-based volumetric machine counts (*12*).

Modeling of Vehicle Ownership and Trip Rates

Several differences in modeling approach were needed for the study, but one particular difference of approach from that applied in Western cities was related to the modeling of vehicle ownership and household trip rates. A standard category analysis approach was employed, but it was found that a complete reformulation of the model was needed to meet local conditions.

Initial statistical analysis of the home interview data indicated that a very low correlation existed between vehicle ownership, trip rates, and household income. In contrast, in Western cities, it is generally found that household income is a dominant variable for these transport parameters. In view of this, a new approach had to be adopted for the category analysis model.

Trip End Model Formulation

The first part of the model predicted the distribution of households in each traffic zone among the 30 vehicle availability/family structure categories defined (Table 2). Three steps were involved:

- Predict vehicle availability distribution;
- Predict family structure distribution; and
- Adjust the study area vehicle availability/family structure matrix, until the row and column totals satisfy these constraints (Fratar Method).

TABLE 2 FAMILY STRUCTURE AND VEHICLE AVAILABILITY CATEGORIES FOR QATAR

Family Structure			Vehicle Availability	
Group	House-hold Size	Number Employed	Group	No. of Vehicles per Household
1	1–4	0–2	1	0 (no vehicle)
2	1–4	3–4	2	1 (single vehicle)
3	5–8	0–4	3	2 (multiple vehicles)
4	5–8	5–8	4	3 (multiple vehicles)
5	9+	0–4	5	4+ (multiple vehicles)
6	9+	5+		

A preliminary investigation of the household interview data showed very little correlation between vehicle availability and household income. Other variables that might explain the variation in vehicle availability between traffic zones were therefore investigated by using regression analysis techniques. The results are shown in Table 3. The most useful variables were those that were able to explain the variation in vehicle availability and were also easy to predict. Ethnic group and dwelling type were chosen as being most appropriate.

The household interview data were used to calculate the average numbers of vehicles per household for each of the 30 ethnic group/dwelling type combinations, as defined in the survey (six ethnic groups, five dwelling types). Inspection of these values showed that the 30 categories could be reduced to six valid combinations. The regrouping was carried out on the basis of similarities of particular categories in terms of average household vehicle availability, the number of households in each category, and the ability to estimate the future household distributions.

TABLE 3 ALTERNATIVE VARIABLES POSSIBLY AFFECTING VEHICLE AVAILABILITY IN QATAR

Variable	Percentage Variation in Vehicles per Household Explained
Ethnic group	76.8
Occupation of head of household	57.0
Dwelling type	51.2
Family structure group	39.7
Average household income	1.4

For any traffic zone, it is possible to calculate the average number of vehicles per household, given the number of households in each of the selected six household types. About 73 percent of the variation in vehicles per household between traffic zones could be explained in this way.

The probability (P_n) of a household being in vehicle availability group n is assumed to be given by the following equations (for any zone i):

For vehicle availability group 1 (0 vehicles):

$$P_{0i} = \frac{1}{1 + K_0\,(\beta_i\,C_i)^{N_0}}$$

where

C_i = average number of vehicles per household;
β_i = a locational variable dependent on factors such as accessibility; and
K, N = calibrated coefficients.

For vehicle availability groups 3–5 (n = 2, 3, or 4+ vehicles):

$$P_{ni} = 1 - \frac{1}{1 + K_n\,(\beta_i\,C_i)^{N_n}}$$

For vehicle availability group 2 (1 vehicle):

$$P_{1i} = 1 - (P_{0i} + P_{2i} + P_{3i} + P_{4i})$$

Values of $K_0, N_0, K_2, N_2, K_3, N_3, K_4, N_4$ were derived from the survey data by variable transformation and multiple linear regression at a zonal level.

The Oman Capital Area Traffic Model Example

Background

The Capital Area of the Sultanate of Oman is a wide region, covering almost 600 km^2 of developable land. The area includes traditional urban settlements such as the old town of Muscat, new town communities, a new central business district, rural village-type settlements, industrial areas, two major seaports, an international airport, and a petroleum plant and refinery.

The past 2 decades have witnessed a rapid and sustained growth in the economy of Oman. This growth has largely stemmed from the utilization of the sultanate's oil and gas reserves and has accelerated with the rise in the world oil prices in the late 1970s and early 1980s. The vehicle fleet increased six-fold between 1976 and 1985, following a four-fold growth in GDP over the same period. The Capital Area has been the main growth pole in the sultanate. Its population has quadrupled in 10 years, from an estimated 56,000 people in 1970 to 226,000 in 1980, and has continued to grow at over 10 percent per annum thereafter.

The objectives of the study (*13, 14*) were first, to develop a strategic traffic model that could be used to test network proposals over short-, medium-, and long-term planning horizons, and second, to establish an efficient road and traffic data collection and processing system.

Model Specification

The terms of reference for the study called for the development and calibration of a strategic traffic model that was to be based on sound data. The modeling methodology had to make maximum use of data that were already available, augmented with data from new traffic surveys. The model had to be simple but robust and capable of making forecasts that reflected the impact of the development of new communities and of new strategic highway links. The methodology also had to indicate how the results of the model could be used to evaluate alternative network configurations and phasing strategies.

No national census had ever been undertaken, and a household interview survey was ruled out. New traffic surveys therefore had to be confined to roadside interviews and traffic counts.

Traffic Surveys

The traffic surveys comprised

- Roadside interviews with a sample of travelers at key locations;
- Bus surveys, including on-board passenger interviews and counts;
- Manual classified counts;
- Automatic traffic counts;
- Journey time surveys;
- Vehicle occupancy counts; and
- Highway network inventory.

To obtain information on the relationship between trip making, vehicle availability, and household characteristics, four additional questions were included in the interview surveys, namely,

- The number of vehicles available to the traveler's household (including vehicles provided by employers), and
- The dwelling type of the traveler's household (i.e., villa, modern house, flat, traditional Omani house, other), as proxy for household income;

in combination with

- Nationality of the traveler, and
- The location of traveler's residence (if not already surveyed, i.e., for non-home-based trips).

The travel and household characteristics obtained from the interviews had to be related to zonal planning data. Planning information was assembled from available records held by various authorities in the sultanate.

The planning data were referenced to the study zoning system. The Capital Area was divided into 121 zones of suitable size, reflecting the local characteristics. The internal zones could be aggregated into 10 sectors for examining broader travel patterns. Areas outside the capital, both within the sultanate and further afield, were grouped into 27 external zones.

Modeling Methodology

The modeling methodology, which was developed on the basis of the model specification, the data availability, and the transport planning needs, was as follows.

First, by using roadside interviews and the "partial matrix" technique, a first estimate of the base year origin-destination trip matrix was obtained.

Second, by using traffic counts and the "matrix estimation from the volume counts" technique (*15*), the unobserved parts of the trip matrix from the first step were adjusted until they reproduced the observed traffic flows.

Third, by using available zonal land use data and the resulting trip ends of the adjusted matrix from the second step, a trip end model was calibrated. This model took into account vehicle availability on the basis of household trip generation rates by mode and purpose.

Fourth, by using a base year network description and the adjusted trip matrix from the second step, a gravity trip distribution model (by mode and purpose) was calibrated.

Finally, by using the trip end model from the third step and trip distribution model from the fourth step, a synthesized base year matrix was obtained. The resulting matrix was assigned to the base year network, and the flows were checked against counts.

Summary of Typical Urban Study Problems

The two urban study examples cited above illustrate certain typical developing world urban traffic study issues. For example, urban size, vehicle ownership, and transport demand in Third World cities are often growing at a considerably faster rate than has ever been experienced in the West. Basic statistical data (census data) are often not available, and home interview surveys may be socially unacceptable or administratively very difficult. In addition, trip-making behavior and vehicle ownership may follow a very different pattern from those in the West.

The examples show, however, that existing models may be reformulated to match local transport behavior. In addition, for those cases in which obtaining data in a traditional manner (e.g., home interviews) is impractical, the data can sometimes be obtained by other means.

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