Derivation of Value of Time and Traffic Demand Curves in Bangkok

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A value of time has been calculated by calibrating a traffic assignment model to match toll expressway usage in Bangkok. This model was developed to reflect the situation in Bangkok, in which extreme traffic congestion and the resulting suppressed traffic demand are common. The values of time derived for models are considerably higher than those derived from income data using either government statistics or home interview survey data, suggesting the unreliability of statistics obtained in the normal manner. A demand curve for expressway travel was then established by extending this method and applied to forecast use of a proposed expressway. The curve derived from the model suggests a demand shift (an upward and clockwise shift of the demand curve) in the future with declining demand elasticity with respect to toll levels as a consequence of increased traffic congestion and real value of time.

Determining the value of time is critical in making urban transport investment decisions. The value of time heavily affects both demand and quantification of economic benefits. The level of demand determines the amount of needed investment; the level of benefit determines the feasibility of the investment. The value of time as perceived by transport facility users is an important determinant of users' behavior (behavioral value of time), whereas the value of time as a limited economic resource is considered to be the basis of economic feasibility determination (resource value of time).

Much theoretical and practical work has been undertaken, mostly in developed countries, to determine the value of time. The emphasis of such work is now moving to limited but carefully controlled and detailed field surveys.

Rapid urbanization throughout the developing world is saturating the limited transport infrastructure of its major cities, requiring solutions. Funds are in short supply, as are planning data, including those required to calculate the value of time. This paper presents the approach to estimating the value of time (behavioral) that was used in a major urban toll expressway planning exercise in Bangkok, Thailand. As an extension of the approach, this paper also presents a method of determining a demand curve for the urban toll expressway.

ESTIMATING THE VALUE OF TIME

Alternative Approaches

Many methods to define and quantify the value of time have been proposed. A classification and discussion of the alternatives in Figure 1 are provided by Suzuki et al. (*1*).

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Practical Problems

The income method is normally applied as a shortcut in developing countries for determining not only resource value but also behavioral value. This method is used to explain travel behavior with some modifications by analogy to data developed in other countries. Income data in developing countries, however, often are unreliable. Top incomes are understated, and the poor are to a large extent outside of the monetary economy. Data on individuals' travel patterns are lacking, and the limited study resources available are inadequate to research them.

The study of a proposed toll expressway in Bangkok presented the authors with such problems. A new urban toll expressway was being planned for the Bangkok metropolitan area, and a major issue was the sensitivity of demand to the toll rate, which would determine the financial viability of the project. The toll on the existing expressway has remained unchanged since the system opened in 1981, so the price elasticity of demand has never been tested. No survey data relating travel patterns to journey times and costs were available. However, areawide origin and destination data did exist. Therefore, the authors attempted to overcome the obstacle by taking advantage of traffic data available for the existing toll expressway.

Methodology

A variant of the route choice model method shown in Figure 1 was applied. Ordinarily, the route choice model method attempts to establish an explanatory function that includes travel time and costs as variable data of trip makers taking a set of competing routes. The ratio of coefficients to travel time and travel cost variables is taken as the value of time. However, direct application to an urban area where there are many alternative routes is difficult.

A simple and direct approach was devised, taking advantage of the situation in Bangkok. The existing toll expressway network basically covers only the central part of the large metropolitan area, as shown in Figure 2. Traffic volume data are available by toll plaza location. Also available to the authors (courtesy of the government of Thailand) were the results of large-scale home and roadside interview surveys undertaken by the Japan International Cooperation Agency in 1989 (*2*). Origin and destination (O-D) tables were developed from these data. A cross-sectional approach was adopted because these detailed O-D data were available only for 1989.

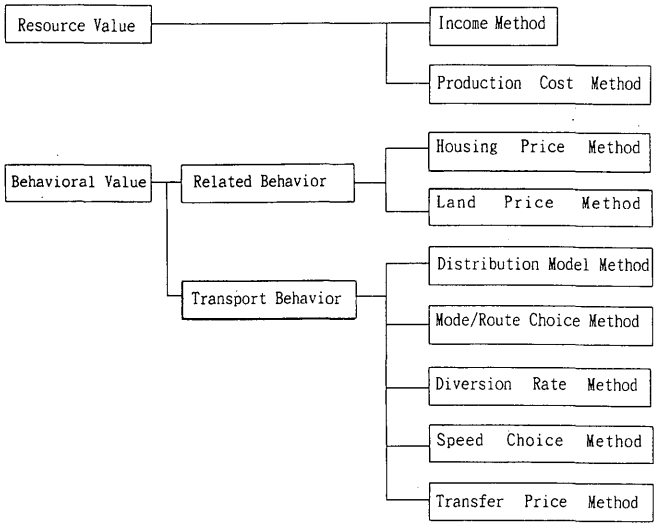

FIGURE 1 Classification of measurement methods.

The six-step procedure adopted was as follows:

1. Vehicular O-D tables were developed and calibrated to match actual traffic volumes throughout the metropolitan area, excluding those on the toll expressway network. The routes of the existing toll expressway and their connections to streets are such that the final calibrated O-D tables could be considered accurate for the purpose of estimating expressway usage.
2. The resultant O-D tables were assigned to the network, with the expressway links included. The expressway toll, 10 Baht (U.S. $0.40) for light vehicles and 20 Baht (U.S. $0.80) for heavy vehicles, was converted to a time penalty for the assignment step. After assignment, model-estimated traffic volumes on each of the toll plazas were checked with actual records to ascertain the validity. Link speeds and travel times were also checked with actual records, and necessary modifications were made to attain a reasonable level of matching.
3. The process was repeated using different time values to convert the monetary toll cost into a different time penalty.
4. A curve relating time value and expressway usage was established.
5. A behavioral value of time was determined by matching the actual traffic volume totals by toll plaza location with the value of time versus traffic volume curve developed above.
6. Steps 1 through 5 above were repeated using the above-obtained value of time to ascertain the results.

Traffic modeling was carried out using the MOTORS suite of programs (microcomputer-based software), originally developed by Steer Davies & Gleave of the United Kingdom. This MS-DOS–based suite has been upgraded and enhanced by PADECO to simulate the extraordinary congestion in Bangkok.

The traffic assignment method used for this study was an incremental assignment on an hourly basis. Link travel times were updated after each incremental assignment and the next incremental assignment loaded traffic onto the shortest path using the updated link travel times. The degree of congestion in Bangkok is such that over 30 iterative assignments were necessary for each hour. Later assignment iterations amounted to less than 1 percent of the total demand. Because the model was primarily calibrated against actual traffic volumes on network links, assigned link volumes matched actual traffic volumes well. Travel times or speeds on each of the network links produced by the model were found to correspond closely with the actual values. Figure 3 shows survey and model results for major arterials. It is evident from this figure how horrendous the level of congestion is in Bangkok.

The selection of the toll expressway by the model as part of the shortest path depends on how the toll expressway network is connected to the zone centroids in the model network representation. Traffic volumes assigned to the toll expressway, therefore, could vary depending on the level of detail of the modeled network. Two levels of detail were tested to examine the effect of this factor. First, the model was run for a network with 90 zones representing the entire Bangkok metropolitan area. Then another network with 170 zones was developed, after dividing zones (except external ones) into two or three smaller zones and recoding the appropriate zone connectors to the road network.

Results

Figures 4 and 5 show the resulting relationships between the toll equivalent time and the total combined traffic assigned to the expressway for light vehicles and heavy vehicles, respectively. Actual recorded traffic volumes indicate that the existing toll of 10 Baht for light vehicles is equivalent to about 2.5 min (i.e., the value of time is 4 Baht/min for light vehicles) and that the toll of 20 Baht for heavy vehicles is equivalent to 4.3 min (i.e., the value of time is 4.7 Baht/min for heavy vehicles).

Figure 4 indicates that the division of the area into smaller zones resulted in less traffic on the expressway. As a larger number of alternative routes became available with a more detailed zone representation, some of the short trips found routes that exclude the expressway, resulting in less traffic on the expressway. However, this is not the case for heavy vehicles, as shown in Figure 5, because heavy vehicle trips include few short trips. Further subdivision of the area into even smaller zones did not yield results that were significantly different from the results of the case of 170 zones because such subdivisions produced no significant alternative routes, considering the limited road link length.

The value of time of 4 to 5 Baht/min or 16 to 20 cents/min that was obtained is much higher than even the monetary value of 1 min derived from personal income figures as reported in government statistics or field surveys.

The value of 1 min as calculated from government statistics (and required assumptions) amounts to less than 2 Baht:

1. Average Bangkok household monthly income in 1986: 7,410 Baht (from government household survey in 1986).
2. Estimated 1989 Bangkok household monthly income: 11,322 Baht (nominal increase: 1986–1987, 7.1 percent; 1987–1988, 14.9 percent; and 1988–1989, 24.2 percent).
3. Average number of income earners/household: 1.5 (from government household survey).
4. Average number of income earners/vehicle: 1.3 (assumed on the basis of home interview survey).

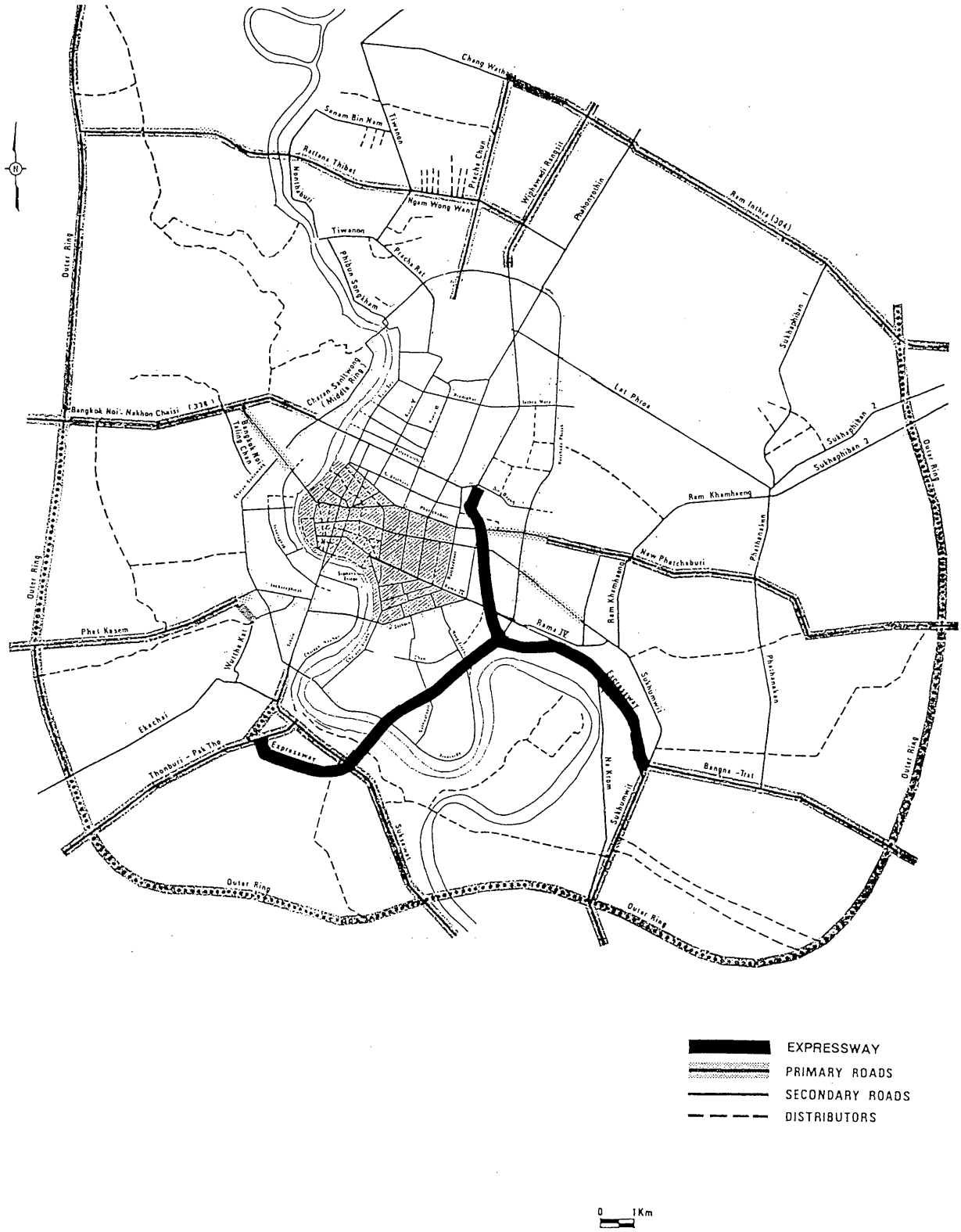

FIGURE 2 Road network in Bangkok.

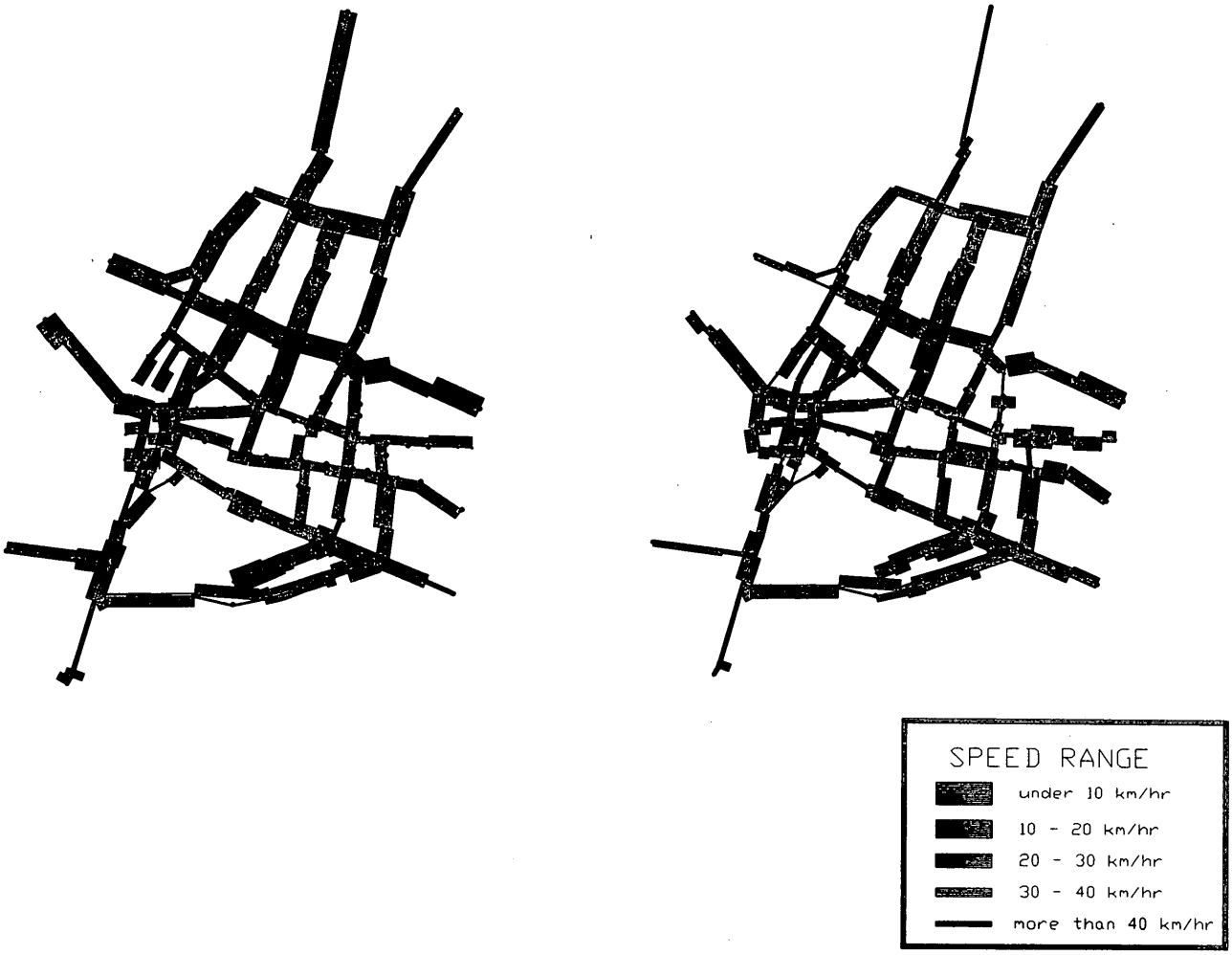

FIGURE 3 Comparison of actual (*left*) and simulated (*right*) network link speed, morning peak, 1989.

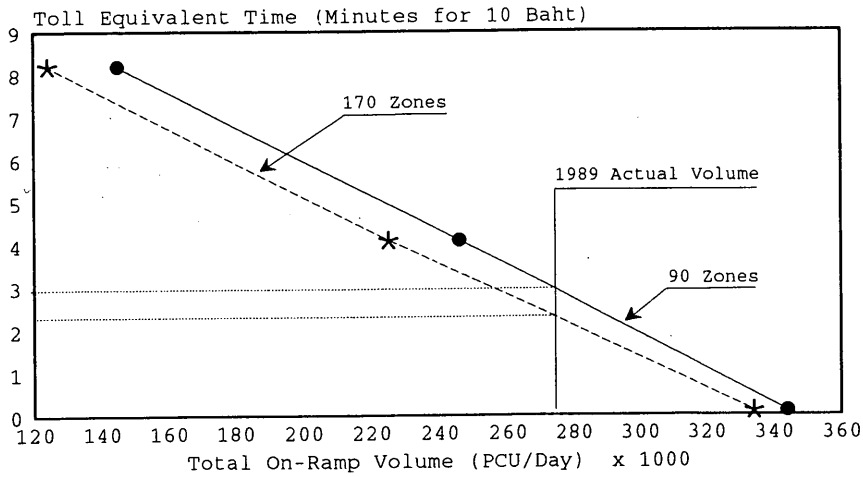

FIGURE 4 Toll equivalent time versus expressway traffic (light vehicles).

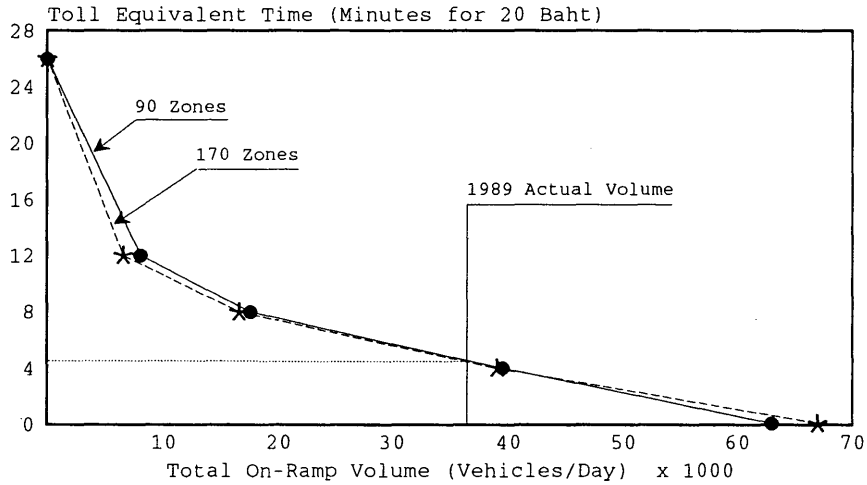

FIGURE 5 Toll equivalent time versus expressway traffic (heavy vehicles).

5. Average number of working hours/month: 170 hr (assumed on the basis of Labor Department data).
6. Ratio of average incomes of top one-third to overall average: 1.63.
7. Hourly passenger income/vehicle: 1.56 Baht/min. (Note: one in three households in Bangkok owns at least one passenger car.)

Many studies in developed countries found that the perceived value of time was less than the hourly wage although the conventional practice of valuing work trip time higher than nonwork trip time is suspect (*3*). The value derived from the actual usage of the expressway turned out to be higher than the hourly wage that was calculated from government statistics and field interview survey results.

Personal income data obtained by a private-sector household survey carried out in 1989 (*2*) also showed lower figures than those expected from the value of time. The average personal income of the three highest-earning occupation groups (i.e., professionals, administrative staff, and shop owners) was 7,665 Baht per person. Assuming 1.3 income earners per vehicle, passenger income per vehicle amounts to less than 1 Baht/min.

The high value of time estimated by the model can primarily be explained by two factors: underestimation of income and truly horrendous traffic congestion. In addition to the underreporting of actual income, the social structure in Bangkok oriented toward extended families may contribute to a higher level of disposable income of individuals than in other societies with less extended-family reliance. Extreme congestion in Bangkok makes journey times utterly unpredictable because of the highly unstable nature of oversaturated traffic flow. A study in the United Kingdom suggested that time savings in highly congested conditions might be valued 40 percent more highly than in less congested conditions (*3*). Values derived in Bangkok suggest such a phenomenon, but even more pronounced. Journey times in Bangkok vary greatly by day. An interview survey conducted by the authors revealed that people tend to report journey times on bad rather than average days. Perceived gains by more predictable alternatives, such as expressway, seem to be much higher than the actual average time savings.

Supporting Evidence

Estimating personal income in Bangkok is an extremely difficult task, and consequently so is estimating the value of time. A recent study attempted to estimate the income levels of private vehicle owners from vehicle purchase prices and purchasing conditions (*4*).

Automobiles and pickups typically are purchased with loans. In July 1990, car loan interest rates ranged from 10 to 15 percent, depending on the model and whether the vehicle was new or used. A down payment of at least 20 percent was required, and repayment of the remaining portion plus interest was to be made over a period of 24 to 48 months. Typically, lenders required that monthly installments not exceed 25 percent of the respective borrower's monthly income. The minimum monthly incomes to satisfy the above conditions were found to be 13,000 Baht for a small 3-year-old (i.e., used) sedan and 41,000 Baht for the new medium-sized sedan that was popular at the time. The model-estimated value of time of 4 to 5 Baht/min corresponds closely with the above-estimated family income of 41,000 Baht/month (3.5 Baht/min).

DEMAND CURVES FOR EXPRESSWAY TRAVEL

Demand Curve, 1989

The value of time obtained above is the average value of all vehicle users that gives the best fit for assigned expressway usage against actual usage. The toll equivalent times (time savings needed to compensate for the toll) in Figures 4 and 5 can be expressed as monetary tolls by multiplying these equivalent times by the average value of time. The point on the vertical axis corresponding to the 1989 actual volume would become 10 Baht and the scale of the vertical axis could be redefined proportionately. The resultant figure would be a demand curve showing the relationship between toll levels and traffic volumes. For light vehicles the curve indicates that a 10 percent increase in the toll level would reduce traffic by 2.3 percent corresponding to a demand elasticity of -0.23.

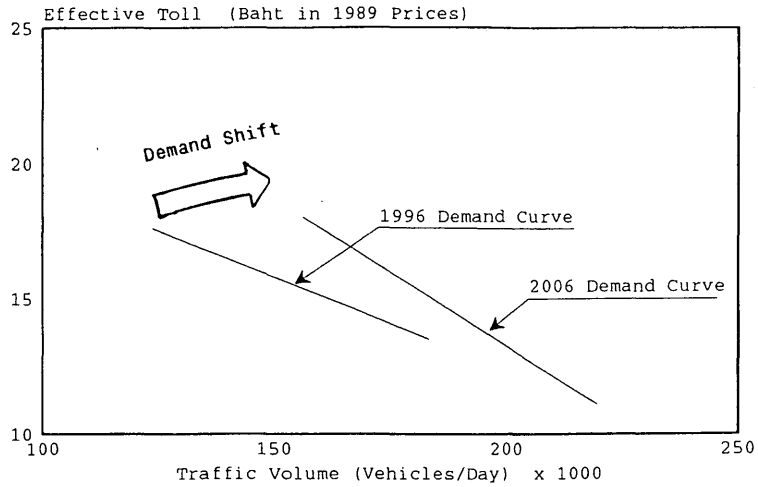

FIGURE 6 Expressway demand curve (northern route, light vehicles).

Future Demand Curves and Demand Shift

This methodology has been applied to estimate loadings on a planned expressway in Bangkok. The forecast O-D trips were assigned to the future network, which included the proposed expressway, for alternative toll levels using the 1989 value of time adjusted for the assumed increase in per capita real income (standard practice in developing countries). The demand curves obtained for 1996 and 2006 are shown in Figure 6. As demand grows between 1996 and 2006 the curve itself rotates clockwise (demand shift), as a result of higher real-time values and greater congestion on alternative nontollway routes. From the future demand curves obtained, future traffic volumes were forecast by applying the proposed toll level expressed in real constant prices.

CONCLUSIONS

A behavioral value of time suitable for forecasting toll expressway demand can be obtained when accurate O-D tables and traffic data on an existing toll system are available. The value determined for Bangkok is higher than that obtained by conventional methods. The methodology provides demand curves (current and future, with respect to toll level) that indicate that the demand elasticity in Bangkok is declining markedly as a result of rapidly increasing real incomes and growing congestion on the nontollway network.

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