Model Improvements for Evaluating Pricing Strategies

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Travel models are commonly used to forecast vehicle-kilometers traveled (vehicle-miles traveled) and speed, from which mobile source emissions are calculated. Most existing models were developed for planning transportation facility improvements and are not well suited for analyzing pricing strategies. Since these models still represent the best available travel database in most urban areas, there is a desire to adapt them to meet a wider range of needs. The Environmental Protection Agency recently commissioned a study on the effects of transport pricing on emissions. This required a planning tool that could analyze many different pricing actions. This project borrowed parts of existing good models to create a pricing-sensitive model set. The resulting model was applied using actual data from one area, for more realistic results. This approach represents an incremental advancement in modeling practice by successfully combining features of the more advanced four-step models. Trip distribution uses a composite definition of impedance that reflects time and cost of all modes. Mode choice is a logit model with some degree of nesting in the carpool mode; it is sensitive to peak and off-peak automobile operating cost, tolls, transit fare, and parking cost. A logit path choice procedure models the effect of tolls on drivers' selection of free and priced paths. All highway paths are based on a combined time and cost impedance. Emissions are sensitive to changes in vehicle age mix, as adjusted based on age- or emissions-based registration fees.

In most larger urbanized areas, a travel forecasting model is used to estimate trip-making activity for future years. This activity is usually expressed in terms of daily or peak hour traffic volumes on each link of the highway network and daily transit passengers. Various other impacts can be derived from these traffic estimates, such as average speed and vehicle-kilometers traveled (VKT) (vehicle-miles traveled [VMT]). Mobile source emissions are then calculated using these statistics.

The detailed nature of most travel models requires that huge amounts of data be provided as inputs. These commonly include estimates of households and jobs by small area (traffic zone), a complete description of the current and future highway and transit systems, and other pertinent information, such as parking cost. Because of the quantities of data needed, computers are required to apply the models and calculate the impacts. Special programs known as travel forecasting software have been written to facilitate the application of complex travel models in urbanized areas.

Almost all existing travel models were developed for planning major transportation facility improvements. They are sensitive mainly to changes in transportation supply and are not specially designed for policy analysis. In particular, most models are not well suited for analyzing the full range of impact of different transport pricing strategies on travel. Although these models are generally not adequate for assessing the impacts of public policy actions, they still represent the best available data base of travel within most urban areas. Thus, there is a strong desire either to modify existing models or to develop new models that can meet a wider range of needs. Some areas are doing both: upgrading their existing models while pursuing the development of entirely new model sets.

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The Environmental Protection Agency (EPA) recently commissioned a study on the effects of transport pricing on emissions (*1*). This required a planning tool that could forecast the travel and emissions impacts of many different pricing actions. As resources were not available for calibrating new models, the project borrowed parts from existing good models from around the United States and assembled them into one model set that could be expected to exhibit reasonable sensitivities toward pricing measures.

A side benefit of this approach is that the resulting model would not be biased toward any one urban area, but would represent a composite picture of several areas, which was desirable from a research perspective. The model would, however, be applied using actual data from one metropolitan area, in order to produce more realistic results. (An earlier plan to apply the model using data from several cities was unfortunately dropped due to time and data constraints.) The resulting model set is referred to as the case study model, because it was used to analyze the different market-based case studies for this project. This model is described further in the next section. The focus of this study is on changes in forecasting methodologies; therefore, results of this analysis are not presented. Readers who are interested in the results should consult the EPA report (*1*).

CASE STUDY MODEL SET

Issues in Forecasting

The estimation of pricing impacts on travel is somewhat controversial. It is instructive to review some of the issues of contention as a way of introducing the model specification.

Almost all current travel models are based on cross-sectional survey data, which is a "snapshot" of travel conditions at one particular point in time. This obviously provides no information on how individual travelers actually respond to travel cost changes, because each trip is observed under only one set of pricing conditions. The theory is that if you observe enough travelers under a sufficiently wide variety of travel conditions, then you will be able to derive information about those travelers' sensitivity to cost. Unfortunately, transportation analysts are seldom able to put this theory to a rigorous test.

In response to this problem, some researchers advocate panel surveys, in which a group of travelers is surveyed several times during a multiyear period (these are sometimes called time series surveys). If the sample size is large enough and is exposed to a variety of cost changes, it would seem that this approach would produce reliable estimates of the true sensitivity of travelers to cost changes. Only a few areas in the U.S. (Portland and Seattle, for example) have conducted such surveys, and the resulting models are still being evaluated by the planning community. In a few more years it should be possible to conclude whether this approach produces forecasting tools of higher quality.

Another issue concerns the very nature of the four-step process: are the travel decisions of individuals made sequentially or simultaneously? It is becoming clearer to travel forecasters that an individual's choices of whether to make a trip, where and when to go, and how to get there are not made independently of each other, but are usually connected in some way. Few four-step models recognize this, so some researchers (particularly in California) have developed other approaches that model these decisions in a somewhat more connected fashion. Clearly, if the four-step process is to continue to be of use, it must be modified to improve the linkages between its steps.

When using travel models for evaluating pricing changes, it must be kept in mind that the models try to forecast an equilibrium situation. However, changes in pricing may have nonlinear short- and long-term effects. Moreover, the short- and long-term cost elasticities and responses are likely to be different for different people. For example, analyses of panel data have shown that sometimes people react to changes in transport conditions not right after the change but when they need to reconsider their behavior for other reasons (e.g., change in job). At the risk of oversimplifying the problem, the current discussion ignores this potentially important consideration.

Some travel models do a good job of modeling complex travel relationships, but achieve this accuracy by requiring input data values for future years that are beyond the capabilities of most transportation planners to forecast. The approach taken in this work is that it is preferable for models to use the simplest input variables possible, which must not exceed the model user's ability to estimate them. If complex variables are warranted, then submodels should be developed to forecast their values.

According to the theory of discrete travel modeling, mode choice models that are calibrated using the behavior of individuals should be transferable among urban areas. If the model is properly specified, its input variables will account for most of the differences in behavior among different kinds of people in different urban areas. In fact, various reviews of the coefficients for the logit mode choice models of several U.S. cities reveal some commonality of travelers' sensitivity to cost changes. There are always some exceptions, but for the most part forecasters have been successful in adapting one city's coefficients for use in another city with some measure of confidence. Although we have not yet reached the stage of having a truly generic model set, the central tendencies of certain parameters are high enough such that we can adopt generalized values with a reasonable level of confidence.

Model Specification

As noted above, the case study model set is adapted from travel forecasting models from various urban areas in the United States. This approach was taken in order to save time and to make the best use of available data. Further, despite some of the issues concerning the four-step process, it is still the most widely used and readily understood modeling approach. It was an explicit premise of this project that most of the problems with the four-step process are related to the way in which the steps are applied and other deficiencies in the input data, rather than flaws inherent in the process itself. The project's researchers believed that a model set could be developed that would satisfy the need for specific sensitivity to pricing measures within the context of the four-step process.

Figure 1 is a flowchart depicting the overall structure of the case study model set. The following sections describe how each component of the model was crafted, with emphasis on the nature of the sensitivity to pricing.

Trip Generation

This component is the most traditional part of the model set. Daily person trips produced by households are estimated as a tabular function of the joint number of households by size and vehicles ownership (i.e., standard cross-classification tables). Daily person trips attracted to a zone are estimated as a linear function of the number of households and employment by type. Four trip purposes are used: home-based work, home-based nonwork, non–home-based, and truck. Internal-external trips are estimated as a percentage of total trip ends. Work trip ends are balanced to the attraction total and trip ends for the other purposes are balanced to production totals. The trip rates and attraction equations were derived from the models of Washington, D.C., Dallas, and Minneapolis-St. Paul (*2–4*).

Few trip generation models are sensitive to pricing. There is little convincing documentation that the cost of travel exerts a measurable influence on the total daily person trips made by a household. This is further complicated by the lack of a consistent definition of "cost" in this context, since cost is more clearly understood in terms of a trip between a specific origin and destination. Still, it seems intuitive to suppose that in some way, the cost of travel should have an effect on the number of trips made. Thus, an attempt was made to model this effect indirectly. A California model was found that related the number of vehicles owned by a household to the annual cost of owning a vehicle (*5*). It was hypothesized that changes in vehicle ownership cost (e.g., from an annual emission fee) would change the number of vehicles owned, thus affecting the number of trips made. Unfortunately, not enough documentation on this California model was available, which prohibited further development of this concept.

Considerable research effort has recently been devoted to the phenomenon of trip chaining (defined as a trip with intermediate stops to pursue additional activities) and it is believed that certain types of chaining activity might be sensitive to travel cost. As that research matures, it should be easier to make trip rates sensitive to pricing.

In summary, the case study model's trip generation process is not sensitive to pricing but is representative of typical good practice throughout the United States.

Trip Distribution

In most areas, the distribution of trips from an origin zone to potential destination zones is performed using a gravity model. This model distributes trips as a function of the number of trip attractions and a measure of the separation of the zones. Almost all areas use travel time by automobile as this measure of separation. However, researchers have long known that factors other than highway time play a role in the allocation of trips to destination zones. For exam-

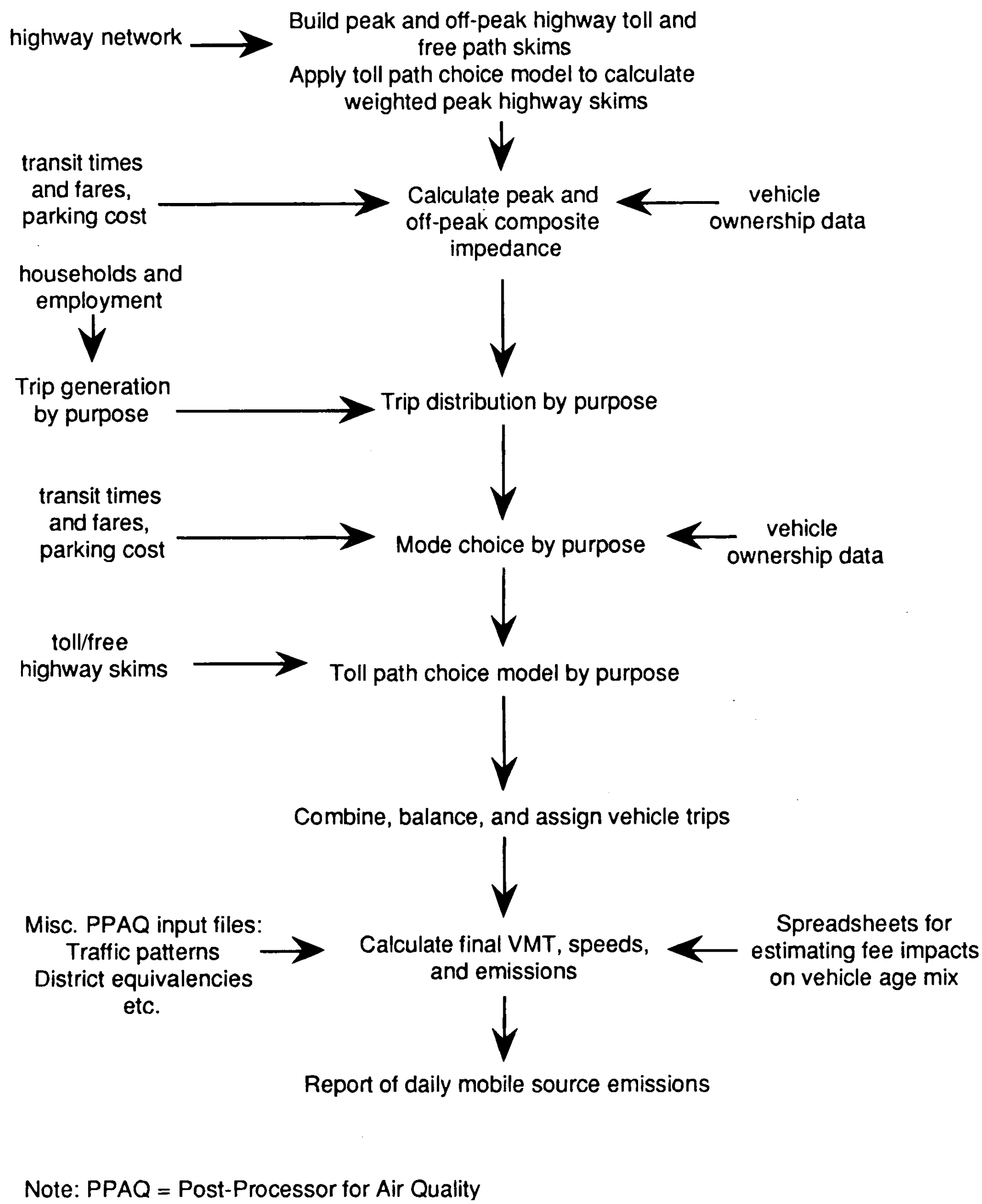

FIGURE 1 Case study travel forecasting model flowchart.

ple, there is considerable evidence that the presence of good transit service between two zones will result in an increase in the number of person trips between those zones. A logical extension of this concept is that other components of this separation, such as cost, should also influence destination choice and thus be accounted for. This effect appears to have an intuitive and empirical basis that cannot be ignored.

So far, very few urban areas have developed distribution models that are sensitive to the cost and service levels of all travel modes (also referred to as composite impedance). Some examples include San Francisco, Boston, New Orleans, Atlanta, and Denver. Most areas that use this formulation use it only for work trips, but in theory it should be applicable to all trip purposes. This is a well-documented process and was adopted for the case study model.

The case study model distributes trips for all purposes with a standard gravity model that uses composite impedance as its measure of zonal separation. This impedance is defined as the log sum from the mode choice model, that is, the natural logarithm of the sum of the exponentiated disutilities of all available travel modes (the denominator of the mode choice equation). This method was adopted from the New Orleans regional model. This version of composite impedance includes all incremental travel costs: automobile operation, tolls, transit fares, and parking. The use of this function makes the allocation of trips to destination zones sensitive to differences in those costs. For example, if transit fares were to decrease in a certain corridor, not only would the transit share increase for those trips (from the mode choice model), but the number of person trips in that corridor would increase, because the decrease in fare causes a decrease in the separation between zones in that corridor. Further, using information from the mode choice model addresses the need for model connectivity, even though the models are still applied sequentially.

In the New Orleans model, composite impedance is used to distribute work trips but not nonwork trips. In the calibration of that model, it was found that travel costs and transit service were uncertain influences on nonwork destination choice. However, it seems reasonable that travel cost should affect nonwork trip patterns in some way, so the case study model uses composite impedance to distribute home-based other, non–home-based, truck, and external trips as well. The case study distribution models were calibrated so as to match overall average trip lengths by purpose, as had been previously reported for the Washington area. *K* factors were used to reduce the tendency of trips to cross the Potomac River.

Mode Choice

Within the four-step process, current mode choice models stand out as being the most rigorously developed and properly cost-sensitive component. Many larger urban areas have developed sophisticated logit models that estimate the share of person trips by mode, based on the socioeconomic level of the traveler and the time and cost attributes of the various modes. The case study mode choice model is based on the approach used in the Washington, D.C. area, which is considered typical of advanced practice (*3,4*).

The mode choice model splits person trips into transit, drive-alone, and carpool modes. Carpool trips are subsequently split among two-person carpools, three-person carpools, and four-or-more-person carpools. Those percentages are used to estimate the average attributes of the carpool mode, which are used in the main mode split. Separate walk-access and drive-access markets are used to calculate the transit split. These calculations are sensitive to various automobile attributes, including terminal time, driving time, automobile operating cost, tolls, and parking cost, as well as transit attributes such as walk time, initial wait time, transfer time, in-vehicle time, and transit fare. A special high-occupancy vehicle (HOV) feature allows the user to define HOVs as having two, three, or four or more persons per vehicle and uses special travel times and costs for such trips. The Washington model's coefficient values were replaced with those representing an average of experience from around the country (which, interestingly, were not substantially different from the Washington coefficient values).

Path Choice and Traffic Assignment

Studies of toll roads focus on drivers' trade-off between paying a toll and saving time. Traditionally, relatively less attention has been paid to drivers' path choices, as planners have relied mainly on traffic assignment software to handle that task. However, recent toll road studies have discovered that such software is inadequate for modeling complex toll versus time trade-offs and have developed more sophisticated models of path choice. These models determine the best free path for each zone-zone pair (i.e, the best path that does not use the toll facility). They then determine the best path that includes the toll facility. Those paths are analyzed to determine their time and toll difference, which is then used in a logit model to estimate the split of trips between the two paths. This is done for every zone-zone pair in the network. Separate toll and time sensitivities are used for work and nonwork trips. Recent advances in assignment software permit the two resulting trip tables to be assigned simultaneously, each to its own set of paths. Within the multiple iterations of assignment, trips are allowed to migrate between paths to a limited degree in response to congestion. The result is a more realistic assignment of trips to toll facilities, in a manner that is sensitive to the level of toll as well as to the capacity of the alternative nontoll routes.

This kind of process has been recently used in toll road studies in Denver and New Jersey, and was adapted for use in the case study model (*6*). It is assumed that this process is suitable for analyzing roadway pricing measures. The resulting toll values affect not only the path choice, but also the mode choice, which uses toll as an input. (The toll value for any zone-zone pair is a weighted average of the tolls on the toll path and the free path: by definition, zero.) Because toll is part of the composite impedance calculation, toll values affect the distribution of trips as well.

The traffic assignment procedure, also adapted from the Washington model, uses four iterations of incremental, capacity-restrained assignment, with 25 percent of the trips assigned on each iteration. Thus, the assignment of trips is sensitive to roadway capacity in an incremental fashion: some trips see an open roadway, while others see a congested one. The input daily vehicle trips are split by four categories: low-occupancy vehicle (LOV) free path, LOV toll path, HOV free path, and HOV toll path. Each category of trips is assigned to its own set of paths on each iteration, respecting the presence of priced roadways and HOV roadways. Finally, the definition of the minimum path for all trips is sensitive to cost, because the path-building criterion is not just time, but a weighted average of time and cost. This weighted average is calculated using $6.00/hour as the average value of time and $0.068/km ($0.11/mile) as the average cost of driving (expressed in 1980 dollars). The output of this process is a loaded network with daily traffic volumes on each link.

Emissions Calculation

The estimation of mobile source emissions requires two basic data items from the traffic assignment: VKT (VMT) and speed. EPA's MOBILE5a emission factor program was applied in this project to calculate emission rates in grams per mile for the criteria pollutants (the EMFAC7F program is used in California). These rates are a function of the mix of vehicles by eight types: the average distance they travel per year, average travel speeds, ambient temperatures, inspection and maintenance programs, and fuel policies, among other factors. The Post-Processor for Air Quality (PPAQ) program (*7*) is used to read the loaded network, recalculate the link speeds by facility type and time period, summarize VKT (VMT) by facility type and time period, and apply the MOBILE5a emission factors. PPAQ requires a series of input tables that reflect the mix of vehicle types by roadway type, the percentage of traffic by hour, and other parameters that describe traffic patterns in more detail. These parameters have been adopted from work recently performed in the Philadelphia region. The result of a PPAQ run is an estimate of total daily kilograms (tons) of HC, CO. and NO_x from mobile sources.

Changes in most of the pricing measures under study, such as roadway pricing, transit fares, and parking costs, are reflected in the assigned link volumes. The exceptions are the measures involving registration fees that are based on age or emission level, and an oldvehicle scrappage program. It was assumed that such strategies have no measurable impact on the number of VKT (VMT), but they will affect the mix of vehicles by age. Strategies that make it more expensive to own an older vehicle should result in fewer older vehicles on the road. Since older vehicles were generally built to less stringent emission standards and are usually less well maintained, a reduction in such vehicles can be expected to reduce the emission rates calculated by MOBILE5a.

Spreadsheets were developed for age-based fees, emission-based fees, and scrappage programs, which estimate the impact of different fee structures and scrappage rates on the default MOBILE5a vehicle mix by year for each of the eight vehicle types. For each vehicle type and year of age, an average vehicle value is estimated. The added cost of registering the vehicle, due to its age or estimated emission level, is compared to that value and an elasticity factor derived from the literature (*8*) is applied to estimate the proportion of that year's vehicles assumed to be taken out of use. Older vehicles removed from the fleet are assumed to be replaced by newer vehicles, in the same proportion as they exist today, so that there is no net change in the number of vehicles, only the average age of the fleet. The output of these spreadsheets is a revised set of vehicle age mixes that can be input directly into MOBILE5a.

Model Application

The case study model set is applied in a series of 15 program steps, most of which use the MINUTP planning software system. Custom FORTRAN programs were written to prepare the land use data and to apply the mode choice model. PPAQ and MOBILE5a are standalone programs and the age mix spreadsheets are in Microsoft Excel. The full model set requires about 9 hours to apply using an 80/486-based computer running at 66 MHz.

The case study model set was applied using basic land use and network data from the Washington, D.C., area (1,478 zones), representing approximate 1996 forecast conditions. However, since the model incorporates components from various cities, the results do not reflect actual or forecasted conditions in Washington and cannot be compared to the results from the Washington area's own model set. The Washington area is projected to comprise about 1.3 million households, 4 million persons, and 3 million jobs. The area has an extensive Interstate system, including the Beltway, which runs around the city and its close-in Maryland and Virginia suburbs. In addition to an extensive bus network, the area is served by the nearly completed 167-km (103-mi) Metrorail system and four commuter rail lines. Major HOV facilities exist in Virginia on Shirley Highway (I-395 and I-95) to the south and I-66 to the west. There is one existing toll road, connecting the Beltway to Dulles International Airport to the west.

As Figure 1 shows, the model set is applied backward, in the sense that the path choice model is applied to derive weighted average highway time, distance, and toll values. Peak period values are used for work trips and off-peak values are used for all other purposes. The mode choice program is then applied to calculate the composite impedance value by zone-zone pair. Next, trip generation and distribution are applied, followed by the mode choice model again, this time to split person trips by mode. Then the path choice model is applied again to split vehicle trips by toll versus free path and the vehicle trips are assigned. Finally, the age mix spreadsheets are applied to determine changes in the age mix, and PPAQ and MOBILE5a are applied to compute emissions from the loaded network.

The case study model has not been calibrated in the true sense, since it was developed from data representing several urban areas. However, the results of the various components were checked for internal consistency and to ensure some approximate level of correspondence with the Washington, D.C. area highway network.

EVALUATION OF THE CASE STUDY MODEL

This section summarizes some of the advanced features of the case study model and identifies some areas of improvement that should be addressed in future research.

Advanced Features

A noted above, the case study model is not based on new research and does not represent any breakthrough in the state of the practice in travel demand modeling. Its advancement is that it was created from the best features from several other well-documented model sets that have been extensively tested through the years. It is very likely the first time that these various components have been assembled in quite this way. This demonstrates one way in which the four-step process can be enhanced to be sensitive to policy issues, such as pricing.

The most noteworthy features of this model set include the following:

- Use of composite impedance for trip distribution for all trip purposes;
- Integration of a toll path–free path choice model within a four-step process;
- Fairly rigorous mode choice model, including a nested carpool occupancy model;
- Parking cost submodel within the mode choice model that estimates separate parking costs for LOVs and HOVs;
- Synthesis of off-peak time and cost values based on peak values;
- Assignment procedures that simultaneously handle LOV versus HOV and toll path–free path trips;
- Ability to easily calculate effects of changes in the vehicle age mix; and
- Integration of mobile source emission calculations within a four-step process.

Areas for Future Improvement

In developing this model set, several shortcomings became apparent. Time and data resources did not permit their resolution, but they are listed here as guidance for enhancing this model set. Additional research should be devoted to these issues in designing future models.

Income Stratification

It would be preferable to stratify the entire model set by income level. This would permit the identification of differential cost sensitivities by income level and would facilitate the examination of the differential effect of pricing policies by income level. As detailed

1990 data on income by trip maker becomes available from the Census Bureau for many urban areas, it will be possible to devote more attention to this issue.

Speed Feedback

The case study model begins with peak and off-peak speed values, the peak speeds having been derived from previous model runs. It would be preferable to run the entire model set at least one more time, using the speeds from the first run (modified as necessary to match observed data more closely) as peak speeds in the second run. However, that would require a total of 18 hours per application, instead of 9. Additional research might identify parts of the model set that would not be affected by speed feedback, thus providing some savings in the running time. As noted above, more effort must be devoted to ensuring that some kind of short-term equilibrium is achieved.

Automobile Access to Transit Trips

Very few models account for automobile access to transit by including such trips in their vehicle trip table. To do so requires data regarding access to transit network (such as Park and Ride lot locations), which was unavailable for this study as well as additional processing steps and time. Still, this phenomenon should not be overlooked, because some improvements to transit service can increase emissions by enticing some who carpool or who walk to transit to switch to driving to transit. Although most drive-access trips are short, they almost always involve a cold engine, and increasing the number of such trips might not be compensated for by the fact that the rest of the trip is made in a transit vehicle.

Parking Cost Sensitivity

Parking cost is probably the most important variable in determining mode choice. Thus, it would be preferable to measure it more carefully, specifically modeling the proportion of travelers who have free parking (instead of accounting for that effect in the average value, as the case study model does). This would require some additional programming effort and detailed data that are difficult to obtain.

Effect of Cost on Trip Generation

In this model set, the trip rate per household or employee is completely insensitive to the incremental cost of travel by any or all modes. This might be remedied by including some kind of zonal composite accessibility measure as part of the trip generation functions. More specific consideration of trip chaining might also address this issue. Some researchers believe that a logical and likely response to increases in the cost of travel is for people to make trips more efficiently. It would be helpful if the model set could reflect this phenomenon. Travel surveys that may have been taken during the time of the 1979–1980 oil crisis could be examined to see if a cost-related effect on the rate of person trips or the type of trips (chained versus non-chained) can be discerned.

Long-Term Land Use Effects

It would be very desirable for the model to adjust the long-term allocation of households and jobs in response to permanent, systemic pricing changes. Care must be taken to separate long-term land use effects from short-term travel decisions. For example, if there were a sharp increase in employee parking cost in an area, some employers would probably decide to move away, resulting in a change in the intensity or character of the area's remaining development. Although this effect would be extremely difficult to calibrate, it might be amenable to some kind of organized sensitivity analysis.

Time of Day

This model set estimates total daily travel only. Although separate peak and off-peak impedances are used to represent those periods, the model does not account for the possible migration of trips from one period to the other. Such migration might occur due to congestion, pricing, or employer policy. Without this feature, the model cannot analyze peak-only pricing measures, which is particularly unfortunate since a probable major response to such measures is to shift the time of travel, more so than the amount or destination or mode of travel.

Nested Logit Model

Although the multinomial logit model is the most widely used formula for mode choice modeling, it is starting to be replaced by the nested logit model. This is because the true nested model is more adept at handling sub-mode splits (e.g., bus versus rail, the transit mode). There is also some evidence that the nested logit structure more closely represents travelers' trade-offs of attributes when selecting a travel mode.

Alternative Composite Impedance Definitions

This model set distributes all trips using a composite measure of time and cost for all modes. The use of such a measure for truck and external trips is questionable. Perhaps a separate combination of highway time and cost, or a different measure altogether, would be more suitable for such trips. In addition, this research disclosed that some hypothesized increases in parking cost for nonwork trips had the effect of slightly increasing average trip lengths, resulting in a net increase in emissions. This effect should be investigated more thoroughly.

CONCLUSIONS

A number of conclusions can be reached concerning improvements to travel forecasting procedures in order to make them more useful for modeling transportation pricing strategies and policies.

- The four-step process can be modified and enhanced to be usable for policy analyses involving pricing measures. This approach has the advantage that such a model can be assembled fairly quickly and uses components that have a proven track record in other areas.

• This analysis makes it clear that time of day models are necessary in order to handle peak-period–only pricing measures. Such models should be sensitive to congestion, peak versus off-peak pricing, and employer policies (perhaps related to employment type). The pricing relationships will need to be developed either from overseas experience or perhaps from transit ridership data under conditions of differential peak and off-peak fares.

• More research is needed into the effects of pricing on trip generation, including how pricing should be represented in trip rate modeling and how trip chaining is affected. Information from the 1979–1980 oil crisis should be further examined to discover any such effects.

• This study's use of composite impedance to distribute nonwork trips should be reexamined. Few, if any, other cities use composite impedance for nonwork trips; it is used only for work trips. More research is needed to determine whether the combined time and cost of all available modes affect the selection of nonwork destinations in the same manner as they appear to affect work destinations.

• More desktop computing power is needed in order to gainfully apply complex model sets like this one, in which pricing is integrated throughout the model chain. Because of this integration, almost any change in pricing requires the entire model to be applied, which can be very time-consuming.

• Today, almost all applications of travel forecasting models are accompanied by the need to determine the impact on mobile source emissions. Thus, an integrated step to adjust network speeds, account for other assignment irregularities, accumulate VKT (VMT), and apply emission factors becomes a necessity. This study's use of the PPAQ program greatly facilitated the analysis of emissions impacts.

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