A Critical Review of Statewide Travel Forecasting Practice

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INTRODUCTION

ISTEA (and now TEA 21) has stimulated greater interest in the development of statewide travel forecasting methods. Several states are now in the process of updating existing travel models and several other states are investigating the possibility of developing new models. In order to provide assistance to these states, the Federal Highway Administration has sponsored the creation of a guidebook and a short course on statewide travel forecasting. In the process of writing the guidebook, the authors reviewed and critiqued current practice and compared it with recent innovations in urban travel forecasting and with state-of-the-art methods from the academic literature. The review was facilitated by an informal survey of 45 of the 50 states, which was validated against similar recent surveys by the University of Wyoming (*1*), the State of Nebraska, and the Transportation Research Board.

Early interviews with individuals involved in statewide travel forecasting indicated that the application of models was highly uneven across states. The levels of sophistication of approaches varied greatly, including data collection methods, calibration procedures, range of modes, range of purposes, network structure, and individual model steps. Some individuals expressed concern that current models were inadequate for a full range of policy testing and that the cost of a model was high compared with its usefulness in many states. Furthermore, there was concern that states without models were not using the best available statistical methods for extrapolating current trends into the future. These concerns became the primary focus of the informal survey.

As part of the informal survey, states were requested to provide any documentation that may exist as to their forecasting techniques. Such documentation consisted of consultant reports, in-house memoranda, letters, and material from personal files. In addition, a search of the published literature was conducted to determine methods that may have been used by states in the past. Very little was found in the way of published material -- such material tending to be quite old and of questionable relevancy. A more fruitful effort was a search of the academic literature on intercity travel forecasting. This search yielded numerous techniques that have not been implemented in statewide models, indicating the possibility of a substantial gap between what states are doing and what states could be doing.

It may be argued that states have been handicapped by a lack of research and software tools. Those states with models have essentially adapted an urban modeling framework. There are many similarities between urban and statewide travel, which makes urban modeling software attractive for statewide models. However, there are also many differences that are difficult to accommodate within existing urban modeling software packages. Thus, this review also attempted to find those parts of urban modeling techniques needing improvement before they can become truly effective for statewide models. The obtained documents from the states are helpful in this regard, as they often showed frustration with the available tools.

A MATURE STATEWIDE PASSENGER MODEL

Arguably the two maturest statewide passenger travel models are from Michigan (*2*) and Kentucky (*3*). These are essentially three-step, single-mode, models that have undergone a considerable amount of refinement over the years and share many similarities. Michigan, in particular, has exhaustively documented each step in the model and each assumption made, so it is possible to use this model as an indicator of the state-of-the practice. Other states with existing models include: Connecticut (*4*), California, Florida (*5*), New Jersey (*6*,*7*), and Vermont (*8*). Still more states have models at various stages of development.

The Michigan model (*2*) retains the characteristics of an urban model -- many traffic analysis zones (TAZ), many purposes -- but on a much larger scale. The model forecasts travel for five trip purposes between 2392 TAZs. Most of the TAZs appear to correspond to townships, with smaller TAZs in large urban areas and larger TAZs in rural areas. The vast majority (2307) of the TAZs are within Michigan while the remaining 85 represent the other 47 contiguous states, Canada, and Mexico. In addition, the model includes thousands of special generator sites, divided into 10 general categories by type of facility. These sites are located within TAZs.

Michigan's initiates its model with socioeconomic forecasts at the county level from a proprietary commercial econometric model. County data is further disaggregated to a TAZ-level using data from the Michigan Employment Security Commission. Census data from the Public Use Microdata Sample (PUMS) and the Census Transportation Planning Package (CTPP) are used to develop cross-classification tables based on five different household sizes and three income groups for a total of 15 categories. PUMS data are available for Public Use Microdata Areas (PUMA), of which there are just 67 in Michigan.

The trip production step for internal trips involves the use of equations for trip production from the as-yet-unpublished update to NCHRP Report #187, "Quick Response Urban Travel Estimation Techniques and Transferable Parameters". These production rates are distributed to the five trip purposes according to proportions from the National Personal Transportation Survey (NPTS), and are applied to the 15 cross-classification categories noted previously, further classified by four city sizes and rural. Equations for internal trip attractions are based on an evaluation of alternative rates generated from the NPTS, metropolitan area studies in Michigan, and available data from the San Francisco area.

The numerous special generator sites are evaluated as having attraction values only. The Institute of Transportation Engineers' *Trip Generation* was used (along with local surveys) to develop the attraction equations. The trips attracted to the special generator sites are only for the home-based social/recreational and home-based other purposes, since a preliminary analysis revealed that attractions for the other purposes were inconsequential. For trips with ends outside of Michigan, production and attraction equations were developed using the NPTS for trips greater than 75 miles in length. Trips from states not represented in the NPTS are estimated as a function of the area of the state in question.

Trip distribution is accomplished using a gravity model. Friction factors (F_{ij}) for the gravity model are calculated using a "gamma" function of the generalized cost of travel (T).

$$F_{ij} = aT^{b}e^{cT}$$

where a, b and c are calibrated parameters. The "gamma" function was chosen to provide maximum flexibility in accounting for both the very short and very long trips that are possible in a statewide model. The gravity model was calibrated using NPTS data and validated using CTPP and traffic count data. Three types of "geographic adjustment" factors (K-factors) are also used in calibrating the gravity model. These K-factors are based on information regarding existing (1) county-to-county, (2) major city-to-city, and (3) outstate/instate traffic flows, and the values of the K-factors listed in the documentation range from as low as 0.10 to as high as 9.67. The impedances for intrazonal trips are calculated separately from the network, however, to avoid complications due to the arbitrary placement of TAZ centroids with respect to highway links.

The model has an elaborate vehicle occupancy step but no mode split step. The vehicle occupancy step consists of three sub-steps. First, a county-level transit share is developed for work trips based on average CTPP shares, and extended to other purposes by using work/non-work ratios from the NPTS. The resulting shares are applied to every TAZ in the county. Second, person trip and vehicle trip data from the NPTS are used to develop average occupancy rates by trip purpose for each of the 15 cross-classification categories. Finally, adjustment factors are developed to account for trip length based again on the NPTS. After applying these occupancy factors, the trips are then assigned to the network using an all-or-nothing algorithm.

It should be noted that the model documentation describes experiments made during model development with proprietary software for synthesizing trip tables based on single-station, origin-destination (OD) surveys, and for employing a "stochastic user equilibrium" algorithm for trip assignment. Both experiments proved unsatisfactory, however, and are not included in normal operation of the model.

Michigan has shown leadership in statewide modeling and their model epitomizes the state-of-the-practice. Michigan's experience also illustrates the numerous problems encountered when an urban modeling framework is used for statewide travel forecasting.

Stitch Models

The model from New Jersey can be described as being stitch model, as it was assembled largely from existing urban models. Stitch models provide for faster network development. Calibration time is reduced when parameters are taken from included urban areas. However, modifications in network structure and zones systems are sometimes done to reduce need for computer resources. Under any circumstances the models must be revalidated to statewide traffic data. Florida also heavily used urban model inputs in their statewide model, but drew an entirely new network and filled in demographic data from rural areas.

A MATURE STATEWIDE FREIGHT MODEL

For various reasons, it has been suggested that forecasting freight transportation flows is more complex than modeling passenger travel volumes (*9*). This is partly because of the numerous parties involved in shipping the large variety of commodities that are regularly moved by the several modes available. The development of freight forecasting techniques, therefore, has historically lagged behind the development of passenger techniques. At the same time, the methods of analyzing freight traffic at a statewide level have remained similar in form to those used in predicting passenger travel. There are essentially two ways that state DOTs forecast freight traffic: (1) by analyzing truck traffic as done in Michigan (*2*); or (2) by using a commodity flow model (*10*).

Indiana (*11*) has the best documented of all statewide freight models and is similar in design to models developed in other states, including Wisconsin (*12*), California, and New Jersey (*13*). The Indiana model predicts both truck and rail traffic volumes for a network that includes a TAZ for each of Indiana's 92 counties, and 53 more TAZs that represent the remaining 47 contiguous states and the District of Columbia. Both the truck and rail networks were developed from U.S. DOT sources. It should be noted that the detailed roadway network for the Indiana freight model extends to about 200 miles beyond the state's border.

The actual workings of the model are very similar to a typical urban model. For each of 21 commodity groups that are considered important to Indiana, trip generation equations were developed based on a regression of data available from the 1993 Commodity Flow Survey (CFS), nationally. Forecasts for Indiana county productions and attractions are then based on county-level employment and population projections. For areas outside of Indiana, forecasts are based on national growth factors.

Following trip generation, freight shipments are distributed by a gravity model that is also calibrated using the national CFS data. Special care has been taken to match the average shipping distance per ton for each commodity group. This prevents an inappropriate weighting for many short-distance lightweight deliveries versus a few long-distance heavyweight shipments that might be included in the same commodity group. The mode split step also utilizes the 1993 CFS, projecting the 1993 national shares into the future. Mode split for any commodity is a function of distance, only.

Before assigning traffic to the network, the Indiana model divides the freight tonnages into an equivalent number of vehicles, with tons-per-vehicle rates determined separately for each commodity group. The rates are based on values (by commodity group) from the Rail Waybill Sample, and the assumption that each truckload carries 40% of the load carried by a railcar. A daily traffic assumption is made for the Indiana model as well, assuming 5 working weekdays and (from the *Highway Capacity Manual*) 0.44 working days for each weekend day. This results in a 5.88 day work week, or a 306 day shipping year.

Finally, the traffic is assigned to the network using an all-or-nothing algorithm. A procedure to adjust the link speeds for non-Interstate highway segments is provided, however, since an unmodified all-or-nothing assignment typically loads too many trips onto Interstate highways. Another adjustment is made to the railroad network to account for the tendency of railroads to route cars by mainlines, ignoring many of the shortest paths.

OTHER METHODS

Time Series

Many of the state DOT officials contacted for FHWA's guidebook indicated that the only forecasts they make are based on the extrapolation of trends observed in historical data. Minnesota DOT has formalized this process as it applies to forecasting traffic for their state trunk highways (*14*), but such documentation seems to be the exception. WisDOT uses linear regression trend analysis, introducing some curvature with Box-Cox transformations. In addition, one state admitted to using a growth factor method, similar to the method outlined for updating coverage counts in the FHWA's 1992 *Traffic Monitoring Guide* (*15*), for forecasting purposes.

Some indication of the possibilities of time series analysis is given in an unpublished paper by Harmatuck (*16*) for WisDOT and by Oberhausen and Koppelman (*17*). These authors specifically explored the possibility of Box-Jenkins or ARIMA (autoregressive, integrated, moving average) models. ARIMA models have been widely used in business forecasting but have not been adopted by states for routine traffic forecasts. ARIMA models have the potential to be stronger and more flexible than either linear trend models or growth factor models. ARIMA models allow for the introduction of cyclical patterns, one-time events, and a variety of causal factors (such as employment or total personal income).

Pivot Method

A Texas report (*18*), which includes reviews of circa-1990 models from Florida, Kentucky, and Michigan, concentrates on the details of statewide modeling, especially the difficulties in isolating interzonal trips and the proliferation of K-factors. The authors of the Texas report identified deficiencies in statewide models that make them unsuitable for project-level forecasts. They also suggest that models could be better used for project-level decision making if they could pivot around existing traffic volumes.

A pivot forecast would use a statewide model only to the extent that it can provide a select-link OD table for the project. The OD table would give the relative contributions of each OD pair to the project. Time series methods could then be used to forecast flows between those origins and destinations making a sizable contribution to traffic in the project.

DATA FOR STATEWIDE MODELS

Passenger Data

Passenger travel surveys have been conducted at the statewide level since the earliest days of highway modeling (*19*), and continue to be conducted at the statewide level (*20, 21*). They are relatively expensive to conduct, however, and must be supplemented by other data. Two other options make use of data that is already available: Federal survey data and statewide traffic counts.

The 1990 Census included a journey-to-work (JTW) survey and introduced the CTPP (*22*). The JTW has proved especially useful in estimating home-based work trips on a statewide level, but has been criticized for its lack of information about other purposes (*23*). The CTPP, meanwhile, provides transportation-related information at a TAZ level, which can be readily aggregated into township or county level data for statewide modeling.

Another federal data source is the NPTS conducted by the Federal Highway Administration in 1995. NPTS data, which deals to some degree with intercity travel, have been used in the development of a number of statewide models. Intercity travel is probably better represented in the American Travel Survey. The ATS was conducted in 1995 and 1996 to identify the nature of long distance travel in the U.S. The survey comprised 80,000 households and dealt with trips of 100 miles or more. Person-level and household-level data are available. In addition to the aforementioned Federal government sources, it should also be noted that estimated and forecasted socioeconomic data are also available from a wide variety of state, academic, and commercial organizations.

Freight Data

Freight data, especially for truck analysis techniques, can be collected by survey methods, as has been done recently by the Washington DOT (*24*), but increasingly models are using national-level commodity flow data as their basis. The NCHRP released two reports in the late 1970s (*25, 26*) that began to address the data requirements of statewide freight modeling. These two reports present 228 different sources of data that could be used for freight forecasting. More recently, NCHRP Report #388 (*9*) has provided an update to the list of data sources. Meanwhile, the Bureau of the Census's 1993 Commodity Flow Survey has been used by several states to develop their own commodity flow interactions. A number of private firms also offer (for a fee) access to their collections of historical and forecast data, not only for population and general employment data, but for employment and commodity flows by industry. Much of the currently available data is unfortunately provided only at a Bureau of Economic Analysis (BEA) region, National Transportation Analysis Region (NTAR), or state levels, which are generally too big for statewide analysis. The data must therefore be disaggregated to at least a county level before use. Two commercial databases under development with FHWA sponsorship are aimed at directly providing county-level data.

Traffic Counts

Of course, traffic counts are needed for model validation. For many years state DOTs have had in place systems of traffic counting equipment operating at a statewide scale. Research in the early 1980s (*27, 28, 29*) developed statistical methods of clustering together traffic counts on different roads based on their similar functional and geographical characteristics. By the middle 1980s, in association with the introduction of the FHWA's *Traffic Monitoring Guide* in 1985, Pennsylvania (*30*), Washington (*31*), and New Mexico (*32*) began to re-evaluate their traffic monitoring systems to take advantage of the clustering.

Comprehensive traffic count information is available only at a comparatively few permanent stations. Depending upon a given state's procedures, time of day information may not be readily available for most links. State counting programs would be unable to provide information related to seasonal or weekly variations in traffic on most links, except to the extent these variations can be estimated from permanent stations in a link's cluster. On the positive side, a large number of links in a statewide network have recent counts. For example, Wisconsin counts approximately 30,000 locations on a three-year cycle, although only 142 are permanent.

Discussion of Data Sources

A substantial amount of data is available for statewide travel forecasting, but the data are not easily accessed. National level databases, particularly the NPTS and the ATS, show promise of reducing the need for local data on travel behavior; however, the data comes in the form of person-trip and household-trip records that need a considerable amount of computer analysis before they can become truly useful. For freight forecasting, commercial products are available that pull together many disparate databases. Otherwise, states must rely primarily upon the CFS, whose lowest-level of spatial aggregation is an NTAR. Railroad-specific studies are less handicapped by aggregation problems because of the existence of the Rail Waybill Sample.

RELATED STUDIES

Synthesized Trip Tables

Even with advanced systems for traffic data collection, it is difficult for a state DOT to collect enough data to account for all of the likely paths between OD pairs being examined. To get around this difficulty, optimization methods have been developed to synthesize trip tables from available traffic count information (*33*, *34*, *35*). These methods have subsequently been applied to statewide analyses in Wyoming (*1*, *36*). Attempts have also been made to synthesize trip tables from census data at a sub-state level in New Jersey (*37*).

Recreational Travel

As early as 1963 recreational trips were considered an important enough purpose to warrant separate study (*38*). In fact, in the late 1960s and early 1970s the NCHRP (*39*), Indiana (*40*), Kentucky (*41*), and other states (*42*, *43*) all conducted studies of the special characteristics of recreational travel. Strangely, although Americans seem to have dedicated an increasing amount of time to pursuing recreational activities, the last of these studies was published more than twenty years ago. Since many state economies depend heavily upon recreational activities, it would seem that this trip type might be important enough to require a closer examination than it has received in the past two decades. The Wyoming (*1*) study indicated that peak traffic demand in that state is closely associated with recreational travel. The importance of recreation travel brings into question the appropriateness of using a small set of urban trip purposes in statewide models.

Intercity Passenger Demand Models

Statewide models, in general, have not made effective use of the considerable amount of literature (largely from academic sources) on intercity passenger demand. Intercity models can essentially be divided into four types on the basis of two categories: data and structure. The models can use either aggregate or disaggregate data, and can be of a direct-demand or sequential structure. Intercity travel demand models can be further classified by whether they encompass only a single mode (mode-specific) or multiple modes (total demand) and by which trip purposes they include.

The earliest intercity models were of the direct demand type, and were developed in the 1960s as part of an examination of the Northeast Corridor (*44*). The most famous of these was Quandt and Balmol's abstract mode model (*45*). The reader is referred to the review by Koppelman et al (*44*) for a more complete historical perspective of significant intercity modeling efforts. Particularly interesting contributions to direct demand modeling were provided by Yu (*46*), who introduced regression coefficients that include a time-series component; by Cohen et al (*47*), who attempted to eliminate unmeasured effects with a pivot point technique; by Peers and Bevilacqua (*48*), who introduced a long list of policy-sensitive variables; and Kaplan et al (*49*), who developed the Passenger Oriented Intercity Network Travel Simulation (POINTS) model, a multimodal model that explicitly includes consideration of accessibility to the transportation system.

Disaggregate models typically use a logit formulation to provide a convenient way of including a number of mode-abstract, transportation accessibility, policy related, and behaviorally-based variables in the modeling process. They were thought to be especially useful in the effort to estimate the shifts in mode share that were expected from deregulation in the air and intercity bus industries, and from the anticipated implementation of high-speed rail transportation (*50, 51*). Again, Koppelman et al (*44*) provides a review of many of the earlier disaggregate mode choice models. In addition, Miller (*52*), Forinash (*53*), and Forinash and Koppelman (*54*) provide studies of the various structures (binomial, multinomial, and nested-multinomial) available to more realistically represent the cross-elasticities between modes and to eliminate irrelevant alternatives in the logit mode-split formulation. Notable contributions to disaggregate intercity modeling were provided by Morrison and Winston (*55*), Koppelman (*56*), and Koppelman and Hirsh (*57*), who present multimodal models hierarchical structures.

Another model of interest is the disaggregate direct-demand model developed in the 1980s by the Egypt National Transportation Study (*58, 59*). The Egyptian Intercity Transportation Planning Model, estimates travel on seven modes for travelers in three income levels. It is unusual in its use of disaggregate data in a single equation (direct-demand) format. Also, unlike many intercity passenger models, it includes capacity restraints on the network, most notably for the shortage of passenger rail cars.

A recurring problem in intercity modeling is the absence of mode-specific coefficients for entirely new modes. To overcome this problem in studies about the viability of high speed rail service, Wisconsin and Illinois (*60*) formulated a nested logit model that was calibrated to both revealed and stated preference information. Stated preference questions related to pairwise choices between automobile and each of the four competing modes (airline, bus, conventional rail, and high speed rail).

Intercity Freight Models

As in the case for passenger models, several reviews have been written on the history of intercity freight modeling (*61, 62, 63, 64*). More recent efforts at modeling the whole freight process are studies at the University of Pennsylvania that concentrated on the differences between freight modeling and passenger modeling (*65*); and work at the Universite of Montreal that has developed the STAN model (*66*).

In addition to the models which address the full extent of the freight transportation process, several address only mode split, since a primary concern of freight modeling is the division of the freight flow between competing modes, usually between truck and rail. A clear example of the importance of mode-split models for intercity freight transportation is provided by Lindesmeyer (*67*) who shows the drastic effects on rural freight trucking in Nebraska that were brought about by changes in rail freight practices.

A number of methods have been employed in the effort to understand how freight traffic becomes divided among the available modes. The methods used have included discriminant analysis (*69*) and a diversion matrix method (*67*), as well as the probabilistic methods more familiar to urban mode-split modelers (*70, 71, 72*). Of these studies, the most interesting is the diversion matrix study. Although it was written before the recent explosion of truck/rail intermodal business and is based on an uncomplicated analysis, the study suggests that only about one quarter of total manufactured-goods cargo is really subject to competition between modes. The choice of modes for the vast majority of manufactured-goods, the study concludes, is instead determined by the weight of the shipment and the length of its haul, or by other factors, such as shipper prejudices toward one mode or another.

NCHRP Report #260 (*73*) is perhaps the most widely distributed method for statewide freight forecasting, although no examples of its application could be found. This report included an elaborate mode split step based exclusively on costs of shipment. Shipments were allocated to modes by an all-or-nothing rule, with the lowest cost mode between an OD pair getting all of a particular commodity.

Research in intercity freight transportation has been minimal, compared with the large number of studies on intercity passenger travel. Given that existing statewide freight models have relied on primarily historical data to perform mode split and that causal variables, including cost, have been largely ignored, research is needed to provide better mode split models.

DISCUSSION

Passenger Models

Urban modeling software packages require consistency of zone sizes throughout the whole process. Thus, zone size compromises must be made. For example, Michigan's model is near its practical limit at 2400 zones; however, zones sizes are still comparatively large for traffic assignment purposes. The notion of capacity, which is very important to urban forecasts, is not a factor in statewide forecasts. Link capacities established within urban areas cannot be used because of the reduction in detail required to fit urban areas into the model. There is a dependency on K-factors to achieve acceptable trip tables. The reasons for the K-factors are unclear, but the use of urban trip purpose categories may be a contributor. The lack of a mode split step in the single-mode models of many states somewhat limits the range of policies that can be addressed, although this cannot be considered a flaw, per se. Some states (e.g., Michigan and Kentucky) lacked sufficient local data for calibration, so they used national databases and default parameters. The use of national databases should be considered an expediency rather than a problem, but this strategy causes a simplification in the spatial detail of trip making behavior. Statewide forecasts are typically of a 24-hour time period; so additional assumptions are required to perform a peak-hour forecast. Because of the zonal aggregation in urban areas, there are a large number of intrazonal trips. The number of intrazonal trips have typically estimated from a gravity model, which is largely insensitive to trip making patterns within zones, thereby introducing an appreciable error into the interzonal trips that remain. Furthermore, intrazonal trips are discarded during the assignment step. Interestingly, an earlier incarnation of the Michigan model eliminated intrazonal trips at the trip generation step in order to get a better of estimate interzonal trips at the trip distribution step.

Freight Models

Again urban-style traffic assignment algorithms fail, but for different reasons than with passenger models. The assignment algorithms are not sensitive to the complexities of carrier-shipper interaction, to carrier profit motivations, and to logistical considerations. Fixes to link impedances, as was done in Indiana, are unsatisfactory. Trip distribution by the gravity model appears to be good in commodity-based models, probably because of the large number of separate commodity groups. Getting sufficient commodity flow data at the state level for gravity model calibration is problematic; however, gravity models can be roughly calibrated to national data. Statewide freight models can exploit existing national and commercial databases in other ways. For example, state-to-state commodity flow matrices from the CFS can be quite useful in determining external trip making. Mode split is an important element in freight models and it is essential if commodities form the basis of the trip generation step. Historical mode split tables (e.g., from the CFS) can provide a minimal mode split capability, although these are essentially insensitive to policy changes. A mode split model that fully incorporates the complete logistic costs of shipping, such as proposed in NCHRP #260, would be preferred. However, the experience (or lack thereof) with this approach suggests that a simpler formulation would be more practical in the short term.

Need for Objectives

There is good consensus as to what constitutes best practice in urban modeling, but similar consensus does not exist for statewide models. Because of their size, expense, and numerous required compromises, it is apparently not possible to build an all-round statewide model. Some forecasting tasks may be better handled with time series analysis or with highly-tailored corridor models. Consequently, it is important that the objectives of the model be described well ahead of any decisions on data collection, model structure, computer software, and budget. The objectives should clearly relate to ongoing policy issues and needs of state transportation plans.

Need for Better Algorithms

There is a need to upgrade the algorithms and software for statewide travel forecasting. In some cases better algorithms are already found in the literature and selected software packages may have already implemented them. Some algorithms that would enhance statewide forecasts include: multiclass assignment (with passenger car equivalence factors) for better simulation of the effects of congestion; dynamic assignment to better understand peaking on long intercity trips; ability to vary parameter sets spatially (including friction factors, time-of-day tables, occupancy, production rates and attraction rates); and more spatial detail in traffic assignment (without resorting to microsimulation or arbitrarily fine-grained zone systems), perhaps by having the ability to use different levels of spatial aggregation at different steps in the model.

Interaction between Model Steps

Unlike recent urban models, statewide models contain little or no interaction between model steps. This is understandable in a single-model model without delay calculations. As statewide models evolve, there will be a greater need to look at the interactions between steps, particularly between mode split and trip distribution. The method widely adopted in urban models, the composite utility function, may be inappropriate for long distance passenger travel where modes are segregated by trip length.

Validation Procedures and Quality

Documents from states are unclear as to the distinction between calibration and validation. The two concepts tend to be blended when parameters are transferred from other locales or national defaults. The lack of a national consensus on validation quality is particularly problematic, as model developers have little guidance as to the number and types of facilities to include in the validation, the required rigor of traffic counting programs, measures of accuracy, and means by which calibration data can be separated from validation data.

CONCLUSIONS

Given the difficulty of addressing federally mandated planning factors with time series methods or sketch planning methods, states should be encouraged to build and upgrade their statewide models. Given the wide variety of end products, states need to carefully match their model to well established goals, which are premised on policies and programs needing evaluation.

Current statewide models have not demonstrated their ability to handle project level analysis, but hybrid techniques (such as the pivot method) are a means by which an existing statewide model could provide useful forecasts at the link level.

In the absence of a statewide model, project level forecasts can be accomplished by time series techniques. The ARIMA family of time series models have strengths not found in simple growth factor methods and linear trend models, which are used by many states. Time series models are best when they contain causal variables, such as total personal income of the region.

There is a need for those people involved in the creation of national databases to be sensitive to the requirements of statewide planning. A recurring problem is the coarseness of spatial aggregation or of reported locations of trips internal to a state. However, many of the national databases could be reformatted or aggregated from raw data. These databases include the CFS, NPTS and ATS. In addition, many statewide networks are of national scope, so a reduction of these databases for the needs of statewide modeling could save a considerable amount of duplicative effort. A skeletal national network, reasonably well calibrated, would also assist states in the rapid development of their own networks.

In addition, there is a need for those people involved in developing travel forecasting packages to be sensitive to the requirements of statewide planning. Several, comparatively small changes, would make it easier for states to match travel patterns existing in both rural and urban areas.

Every model step could use better algorithms. Of all the model steps, traffic assignment appears weakest and least correctable. Research is needed to provide traffic assignment algorithms that can give good results in rural areas and at various time periods throughout the day. Special attention needs to be given to the problem of large zones. Other model steps could benefit from methods proven useful in corridor and intercity studies.

Statewide models should be balanced in their treatment of freight and passenger modes. Although freight vehicles represent a small percentage of traffic, they have a disproportionate effect on pavement life, congestion, geometric design considerations, and the state's economy. A modest freight component can be created almost exclusively with readily available databases. A commodity-based model, rather than a vehicle-based model, shows greatest promise. Freight mode split models should include, at the minimum, cost as a causal variable.

Most statewide models have adopted trip purposes from urban models. The appropriateness of this strategy needs reevaluation, as long distance trip making (particularly recreation travel) differs greatly in character from short distance trips.

Finally, there is little consensus on validation standards for statewide models. Research is required on how traffic counting programs can better serve the needs of statewide travel forecasting.

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