Computer Transportation Models for Land Use Regulation and Master Planning in Montgomery County, Maryland

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The evolution of computer transportation modeling in Montgomery County, Maryland, over the past 15 years, is described in this paper along with the ways in which transportation models have been used for planning and growth management. Transportation models have been used to link land development regulation decisions with the budget process for transportation infrastructure provision under the county's Adequate Public Facility Ordinance, with level of service standards for acceptable traffic congestion levels used to set limits on new subdivision activity in parts of the county. Transportation models have been used to evaluate the long-range balance between current zoning and infrastructure projected under the master plan of highways. Build-out of current zoning with planned infrastructure leads to intolerable traffic congestion. By reducing the ratio between jobs and households, clustering employment, and providing a new light rail system connecting major centers of the emerging polycentric metropolitan region, with infrastructure to make the centers bicycle- and pedestrian-friendly, acceptable levels of traffic congestion could be achieved at much higher levels of urbanization. The development of transportation models to support these planning efforts, including calibration of a peak-hour factor model, a nested logit mode choice model sensitive to the quality of pedestrian access to public transportation, and subarea master planning model systems are discussed in this paper. It describes preliminary work in combining Geographic Information Systems (GIS) technology with conventional regional transportation models. It describes how GIS may be the best tool for dealing with transportation behavior variables where the variance in the data within zones exceeds the variance between zones.

Montgomery County, Maryland, is a large, affluent municipality immediately north of Washington, D.C. Until recently, the county was composed largely of bedroom suburban communities, self-sufficient towns, and fertile agricultural areas. In the past several decades, the county has witnessed rapid growth in both employment and housing as the Washington area has developed a more multinucleated metropolitan form. Montgomery County's economic base is focused on biotechnology, information and communications technologies, and activities of the United States government. The county now encompasses 350,000 jobs and 700,000 people in 270,000 households with growth clustered in several urbanized inner-ring satellite cities and spread across the sprawling I-270 growth corridor. Six out of 10 county residents work in the county, while one-fourth work in the District of Columbia.

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In the past several years, traffic congestion and growth policy have become central political issues in many rapidly urbanizing suburban growth areas of America, such as Montgomery County. As the organization responsible for developing master plans and regulating the subdivision of land in Montgomery County, the Maryland National Capital Park and Planning Commission (M-NCPPC) has played an important role in shaping and staging growth in the area.

Since passage of an Adequate Public Facilities Ordinance (APFO) in the mid-1970s, the county has sought to keep growth from outpacing the provision of infrastructure, such as roads, sewers, and schools. This has sometimes led to a moratorium on subdivision approvals for housing or commercial development in selected planning areas across the county and helped stimulate increased investments in infrastructure to support development.

Computer transportation models have been used for nearly a decade as tools to help assess the maximum levels of household and employment growth desirable within different subareas of the county, given programmed transportation improvements. The county has recently been extending the utility of these computer models to assess master plan development issues, staging of capital improvements, long-range regional planning issues, and other matters. This paper reviews the evolution of computer modeling techniques and applications for land use and transport planning in Montgomery County.

EVOLUTION OF COMPUTER TRANSPORT MODELING SYSTEMS IN MONTGOMERY COUNTY

TRIMS

The M-NCPPC began using computer transportation models in 1977 by borrowing, with consultant assistance, the travel demand models and TRIMS modeling software developed by the Washington Metropolitan Council of Governments (COG). This conventional four-step transportation model, similar to UTPS, was run on a remote time-share IBM mainframe computer. A transportation engineer, with support from a computer programmer, maintained the road network and average daily traffic count data base and the land use inputs used by the model. The primary use of the model was to help evaluate how much new growth should be permitted in the subdivision review process in different policy areas of the county based on new roads programmed in the four- to six-year county and state captal budgets, working on an annual regulatory analysis cycle.

In the early 1980s, a citizens advisory committee evaluated the process used to establish growth policy under the APFO and recommended making a number of improvements in the modeling techniques. New staff was brought in to oversee the operation and enhancement of the model system in 1983.

Growth in the county reached unprecedented rates for a prolonged period following the 1982–1983 recession. In the meantime, road construction schedules slipped from those expressed in the capital budgets that had been used to estimate infrastructure available to support new development approvals. This led to noticeable increases in traffic congestion, public outcry against growth, numerous political initiatives to better manage growth and traffic, and strong pressures on the growth management system, computer data bases, and systems used to assess growth and traffic congestion.

Additional resources were made available for computer modeling and data collection, but with unrealistic expectation that near-immediate results could be forthcoming. Long-term system enhancement efforts took back seat to then current applications of the existing computer transportation model, which were handicapped by an obsolete and increasingly dysfunctional mainframe-based data base management system that handled model inputs and outputs.

EMME/2

In 1985, the M-NCPPC purchased the EMME/2 transportation modeling software to obtain its equilibrium assignment techniques, strong transit modeling capabilities, impressive computer graphics display and interactive graphic network editing capabilities, and a flexible framework for model development and calibration. The availability of this more robust and powerful software led to the abandonment of an in-house effort to transfer the TRIMS software and a newly developed data base management system to an HP-3000 owned by the M-NCPPC.

This change enhanced M-NCPPC's in-house capabilities for data management, transportation model development, and the creation of post-processing evaluation programs using programming tools available within the UNIX operating system. It offered the benefits of operating on a user-controlled microcomputer—an HP-9000—rather than on a remote mainframe. It also provided the context for beginning a gradual adaptation, enhancement, and replacement of COG travel demand models with models more sensitive to the policy analysis needs of Montgomery County planners and decision makers.

Over the years, the M-NCPPC has adapted zone and network systems to a variety of scales for different types of transportation model applications. The first step was in converting the COG 1246-zone traffic model to a county-focused system in which 246 zones represented Montgomery County and only 90 zones represented the rest of the Washington region. In recent years, this has been further focused within the county on smaller areas master planning models to obtain a level of detail more desirable for subarea master planning, assessment of new development proposals, and evaluation of community level strategies for transportation system management. These are all areas of extensive M-NCPPC regulatory and planning activity.

These more detailed subarea models retain the 90-zone coarse detail for the region outside Montgomery County, a moderate level of detail (about 200 to 230 zones) within Montgomery County outside the subarea, and great detail (70 to 200 zones) within the selected subareas of the county. Each subarea model data base is coded to operate with EMME/2 computer transportation modeling software, using the M-NCPPC's evolving set of transportation supply and demand models, coded as EMME/2 macros.

With increasingly sophisticated models and a rapid growth in model applications for short- and long-range planning on a subarea, county, and regional level of analysis, there has been a need to expand both staff and computer resources. Today M-NCPPC's Transportation/Land Use Modeling section employs one-half dozen transportation engineers, several planning technicians and interns, and an HP-9000/835 computer supported by 3000 MB of hard disk capacity, plotters, and graphics terminals. At any one time, 30 or more EMME/2 data bases for different model applications are typically in current use status on the system.

SPANS

In late 1988, the M-NCPPC acquired the SPANS Geographic Information System (GIS) to better estimate model inputs from large disaggregate datasets and better display model inputs and outputs. Eventually, the M-NCPPC hopes to develop new hybrid land-use and transportation-planning models that will combine the powerful disaggregate point and vector data manipulation of GIS technology with the network analysis and multidimensional matrix handling capabilities of conventional zone-based transportation models, such as EMME/2.

CALIBRATION OF AN AM PEAK HOUR TRAFFIC MODEL

The initial area for model enhancement when the EMME/2 software was acquired by the M-NCPPC was to calibrate an AM peak hour traffic model. Previously, a daily traffic model with link-specific composite peak-hour factors had been used for most traffic modeling in the Washington, D.C. region. Having a real peak-hour model, as opposed to a composite AM/PM peak-hour model, meant that directional capacity of roads with reversible lanes and uneven directional capacities could be directly represented. The capacity utilization by direction could be measured for more sensitivity to policy choices related to this. Changes in peaking behavior over time due to both urbanization and congestion could be more readily captured.

Moreover, the result of assignments would be traffic loads closely representative of what people encounter going to work, rather than a more abstract composite of both AM and PM peak congestion. Pure AM or PM peak hour assignments exhibit the true directionality of traffic flows typical of many communities. Daily assignments factored to represent composite peak period conditions with balanced directional flows had masked errors in network coding and trip table characteristics due to their ambiguous nature.

The object of the M-NCPPC modeling was the estimation of peak-hour congestion and the adequacy of traffic conditions given certain assumed land-use and network characteristics. With the daily traffic forecasts of the previous TRIMS system, it had been necessary to convert daily volumes to peak-hour volumes or to convert hourly capacities to daily capacities to estimate relative congestion levels.

The solution to this problem had been to assume that for certain road types, some fixed percentage of the total daily traffic would occur in the peak hour or to assume a fixed link-specific factor for the inefficiency of capacity utilization, recognizing that traffic flows demonstrate major peak demands usually twice a day with very low flows late at night. The data on which to determine these factors were very limited, so default factors had been used, that could not readily reflect gradual changes over time in the peaking characteristics of traffic.

Common sense suggests that two key factors influence the peaking characteristics of traffic: (a) the land use density and mix and associated demographic character of an area; and (b) the amount of peak hour congestion in the transportation system.

Small towns, sprawling bedroom communities, and isolated industrial or office parks typically display higher peak-hour factors—that is, a greater portion of the total daily trips are made in the AM and PM peak hours of traffic—than do heterogeneous, high-density, cosmopolitan urban centers. Homogeneous land use areas, whether office centers or residential communities, where the "sidewalks roll up at 6 o'clock," as the saying goes, attract or generate far more of their daily trips in the peak hours than do places that attract human activity both day and night, regardless of the levels of traffic congestion.

Travel corridors and areas with severe peak hour traffic congestion—the famous freeways of Los Angeles, where "rush hour" starts at 5:30 a.m. and ends at 8 p.m., with a slight dip in mid-morning and mid-afternoon, come to mind—also experience fairly flat distributions of daily travel demand, with low peak-hour factors, because the peak periods become very long. In response to increased peak-hour congestion, people with some flexibility start to alter their travel times to avoid the worst traffic conditions. Obviously, there are social, political, and ultimately theoretical limits to the degree of trip-time flexibility and congestion-induced peak-hour spreading.

Conventional approaches that use fixed factors to account for peaking characteristics of traffic obviously cannot hope to deal with either of these two conditions that lead to a lowering of peak-hour factors over time as areas urbanize and congestion increases. The limits of fixed factors became apparent to M-NCPPC staff trying to evaluate peak-hour congestion trends using average daily traffic count data. With the fixed factors, congestion levels of several times the assumed daily capacity were found on more than a few links in rapidly urbanizing formerly rural areas of Montgomery County.

Upon closer analysis, it became clear that the link peak-hour capacity factors needed to be altered to reflect urbanization and corridor congestion. However, with thousands of links in the model, a systematic and automated approach to establish new factors would be needed. An examination of the available traffic count data base yielded more evidence that change was needed but gaps and inaccuracies in the data provided no easy means for reliable calibration of a new link-based model. Indeed, the COG had recently undertaken its own assessment of new link-based peak factors for another jurisdiction with results that looked not too promising.

With installation of the new M-NCPPC EMME/2 model system, an opportunity arose to develop a new approach. The alternate and more direct way to get at the question of peaking of demand was to take daily trip tables and split them to a peak-hour trip-table for assignment.

A large data base of AM and PM peak period turning-movement traffic counts at intersections by half-hour interval was available for a large portion of Montgomery County from the early 1970s to the present, but this data had not been computerized. A half-dozen interns were put to work for some months to code and clean traffic-count data. Rather than seeking traffic counts for a particular hour of the day, it was decided to calibrate the model to the AM peak hour for each intersection, whenever it occurred.

It would have been desirable to develop a PM peak-hour model, as traffic congestion problems are somewhat more severe in the PM than in the AM. However, the majority of trips on the road at that time of day are non-work trips, for which there was little recent data to calibrate models. Because survey data suggested that home-based work trips constituted nearly 80 percent of trips on the road in the AM peak hour, M-NCPPC staff decided to tackle the easier problem first, relying on the 1980 Census trip-table data to help estimate a refined work trip model. A 1980 COG auto use survey of more than 600 households in the Washington region provided data on the percent of automobile trips by purpose by hour of day to help derive trip-table splitting factors.

Rough initial factors for splitting daily trip tables were estimated from the COG survey data: 19 percent of home-based work trips, 3.2 percent of home-based other trips, 1 percent of home-based shop trips, and 3 percent of non-home-based trips were to be assigned to the AM peak-hour highway network. The input trip tables were the observed work trip table from the 1980 Census and simulated non-work tables based on the COG models.

The results were disappointing at first, with substantial oversimulation of vehicle-miles of travel (VMT) in the core areas of the region and substantial undersimulation of VMT in the fringe suburban and rural areas. Then the experimentation began, first with area-based factors, then with density-based factors that adjusted these initial trip-table splitting factors upward and downward.

After several tests of alternate model forms, a simple density-based model was found that produced very close agreement between simulated and observed VMT for both 1980 and 1984. It adjusted the initial regional trip-table splitting factors from the COG auto use survey upward or downward by up to 20 percent at the origin and destination trip ends, based on household density at the origin end and employment density at the destination end. As expected, the lowest trip-table splitting factors were applicable to high-density, mixed land-use areas and the highest splitting factors to low-density, homogeneous areas. The final model is shown in Figure 1.

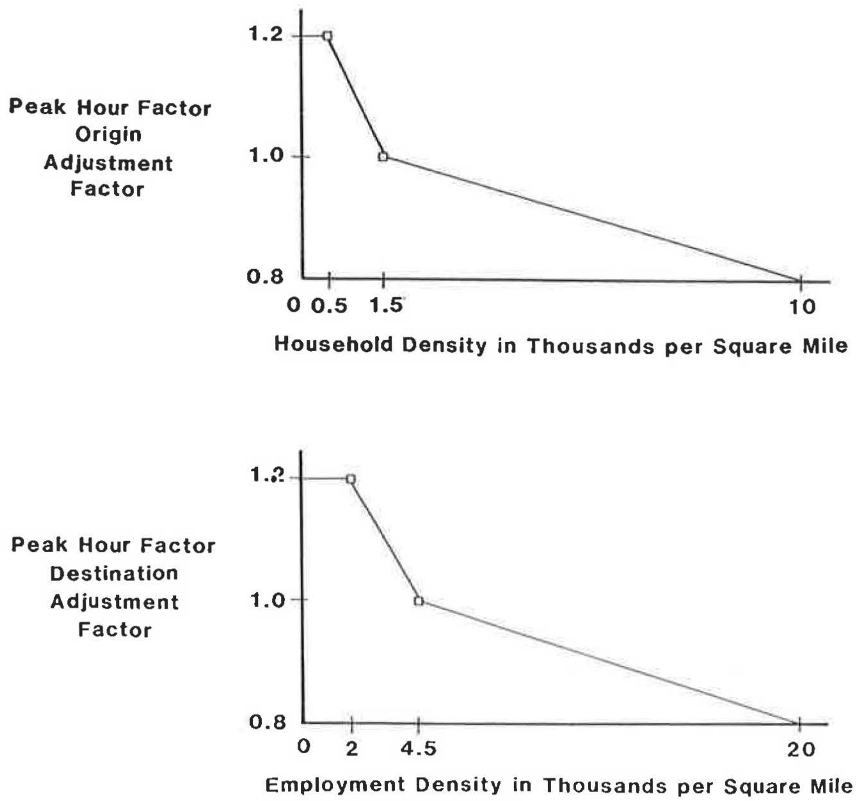

FIGURE 1 AM peak-hour trip-table splitting using density-based adjustment factors to account for effects of sprawl-clustering on peaking of trips.

The resulting AM peak hour model matched within 5 percent VMT and V/C ratio estimates produced from traffic counts for the 20 policy areas of Montgomery County. The model also matched major jurisdiction level VMT quite closely in the Washington region, with network assignments producing a root mean square error (RMSE) of about 26 percent against observed traffic counts (*1*).

Adjustments were made to the model structure to compensate for the relatively large zone size coded in some parts of the Washington region outside of Montgomery County that affected the computed densities. Another refinement was later made to discount home-based work trips in the AM peak hour related to retail employment in those zones with very large amounts of retail employment, in particular the regional shopping malls, where stores typically open at 10 a.m.

This model corroborates the findings of the costs of sprawl studies (*2*) done in the mid-1970s, suggesting that more transportation infrastructure per unit of development is needed when the development is put into low-density areas than if it goes into already built-up areas. It also corresponds to the common sense notion that small-scale, heterogeneous land use, which permits more travel demand to be met by nonmotorized means, similarly requires less transportation infrastructure per unit of development.

This peak-hour trip-table splitting model provides a means of formally accounting for changes in peak-hour factors in response to urbanization over time. Further research with additional data sources is needed to identify the extent to which this empirical model reflects peak spreading due to demographic changes versus the traffic congestion that typically comes with urbanization.

It should be noted that this density-based peak-hour trip-table splitting model does not explicitly account for the impact of congestion on peak spreading. It also has the weakness of introducing distortions in the relative trip distribution of the final peak-hour trip tables.

Because traffic conditions in 1980 in the Washington, D.C. area were not as bad as many other large metropolitan areas, it is presumed that much of the peak spreading simulated by the model is due to urbanization itself. A fruitful research project might be to test elasticities of peak spreading against various cross-classified corridor congestion levels and land use density/heterogeneity conditions in different cities.

Research is being carried out by the M-NCPPC in 1990 with data from a larger and more recent travel survey, with hopes to replace this simple density-based peak-hour factor model with a more refined approach.

CALIBRATION OF A NESTED LOGIT MODE CHOICE MODEL

With the TRIMS model system, the M-NCPPC was forced to use a very crude non-network-based approach to estimate transit mode shares for work trips. Non-work trips were generated as vehicle trips, so no mode share estimation was required to derive vehicle trip tables for highway assignment. When the EMME/2-based AM peak-hour highway model was developed, M-NCPPC staff concurrently developed a data base descriptive of AM peak hour transit services in the Washington, D.C. region and did a quick, crude calibration against 1980 census journey-to-work data of a simple stratified regression work trip transit mode share model with a form borrowed from COG. An extremely simplistic non-network-based cross-classification auto occupancy model used in TRIMS was transferred intact into the EMME/2 framework.

These tools provided temporary support for the growing workload of transportation modeling applications demanded by the M-NCPPC work program, but failed to provide sensitivity to a wide range of alternative public policies that might reduce dependency on the single passenger automobile.

To respond to these policy analysis needs, a new nested logit mode choice model for work trips was calibrated in late 1988 by M-NCPPC with assistance from Comsis Corporation, using 1987–1988 regional travel survey data. The model forecasts the probabilities of using an automobile by auto occupancy class, transit by walking, or automobile access. In addition to the usual model inputs related to travel time and cost by mode, this model is sensitive to transit serviceability factors—the availability of sidewalks and bicycle paths, the degree of heterogeneity of land use at a small scale, building setbacks, and availability of bus stop shelters. These factors have been crudely estimated at the zone level by use of a composite weighted index—the Transit Serviceability Index. For each transportation zone, assess and add the following:

- Sidewalks
  - .00 None
  - .05 Discontinuous and narrow
  - .15 Narrow but along all major streets
  - .25 Adequate width along all major streets
  - .35 Everywhere, augmented with traffic calming or pedestrian streets and shortcuts
  - .45 Full area-wide pedestrian district with restraints on automobile use
- Land use mix
  - .00 Homogeneous within walking distance
  - .10 Some mix of uses within walking distance
  - .20 Moderate density fully mixed use
  - .25 High density fully mixed use
- Building set backs
  - .00 Large (mostly sprawled campus style)
  - .10 Small (mostly abutting street & bus stops)
- Transit stop conditions
  - .00 No bus stop shelters
  - .10 Widely available bus stop shelters
- Bicycle conditions
  - .00 Little or none
  - .05 Some cycle paths and special facilities
  - .10 Network of cycle paths and lanes with good conditions for cyclists to reach centers

Sum total ranges between 0 and 1.0 and comprises the Transit Serviceability Index, or indicator of pedestrian and bicycle friendliness.

This new logit model was developed to better simulate current suburban transit use and improve sensitivity to factors that influence this. Comsis had previously analyzed the performance of a new mode choice model calibrated on 1980 census data for the COG. While the COG model performed well at the regional level and in forecasting transit trips destined to downtown Washington, D.C., it substantially overestimated transit trips to suburban activity centers, even with area-based adjustment factors. For example, the equivalent of 60 minutes of in-vehicle transit time had to be added to trips destined to the North Bethesda area of Montgomery County, an automobile-oriented, high-technology employment center, to match the observed propensity for transit use.

The COG model is typical of mode choice models used in the United States today, being based primarily on in- and out-of-vehicle travel times and travel cost, with some area-to-area adjustment factors. The quality of the transit access and egress system, a very disaggregate fine-grained element of the transportation system, broadly described as transit serviceability, is not a factor of the model. Indeed, the modeler must prespecify the share of access trips for each zone that will walk or drive to transit. M-NCPPC staff believed that inclusion of transit serviceability factors might account for much of the variance in mode choice behavior that remained unexplained by the COG model, especially when comparing automobile-oriented suburban activity centers with more traditional downtowns. Moreover, use of such variables might make it possible for the model to estimate mode of access to transit directly.

Model calibration bore out this hypothesis. Transit serviceability factors at both origin and destination ends of trips statistically proved to be highly explanatory variables, both for propensity to use transit and for means of access to transit (*3*).

In 1990, M-NCPPC staff is importing existing computerized data files on Montgomery County sidewalks, street medians, bus stops, and other factors influencing transit serviceability into SPANS GIS software for more precise quantification of these factors. SPANS or other software will also be used with parcel file, subdivision file, zone and subzone boundary files, and a file showing transit stop locations to calculate, rather than guess at, average weighted walking access distances from zones to transit stops, that can be assigned to walk-centroid connectors used in transit assignments. As data inputs are refined, the logit model will be reestimated using these additional disaggregate variables.

TRANSPORT MODEL STRUCTURE AND COMPUTER TECHNOLOGY

Across the United States, a conventional four-step transportation modeling process (trip generation/trip distribution/mode choice/network assignment) has been used with aggregate zone-based data input for transportation planning since the early 1960s. Montgomery County has been no different.

Zonal aggregation has been the product of practical and cost limits on computer memory and speed that have forced planners to simplify highly complex non-linear disaggregate systems into far simpler and more linear aggregate systems for analysis. With the advances in computer technology over the past decade, however, many of the original reasons for purely aggregate analysis have disappeared. Disaggregate data analysis and modeling is becoming more cost effective as data acquisition, management, analysis, storage, and computing technologies have improved and become less expensive. By making regional transportation models more disaggregate and reflective of the rich spatial variation that exists in living communities, some of the major limitations of classic four-step aggregate zone-based regional transportation models can likely be overcome.

The conventional four-step aggregate zone-based models have demonstrated their utility to simulate traffic flows on major roads in the short term, with some limitations. In general, the finer grained the data one attempts to measure in these systems, the less the reliability in the simulation, which is quite reasonable, given the probabilistic and nonlinear nature of human travel behavior and network flow. The farther out into the future these models forecast, the less likely it is that the actual future system inputs will correspond to the forecast system inputs or that assumed underlying relationships between the factors in the model system will remain stable.

A major limitation of most zone-based regional transportation models is their ignorance of fine-grained spatial variations in the built environment and in urban populations. Hundreds or thousands of households exhibiting and experiencing huge variations in the attributes shaping travel behavior are usually reduced to single zone values representing average characteristics. Often, variance of key attributes within zones exceeds the variance between zones, leading model builders to draw false conclusions from overly aggregated data. For such attributes, GIS technology offers great potential for improving the explanatory power of conventional transportation modeling techniques.

For example, within the confines of a limited number of often large transportation analysis zones, conventional aggregate models usually do a poor job of reflecting true transit access travel times and conditions. Is there a sidewalk people can use to get to a transit stop or are they forced to walk in the street as in so many American suburbs and cities? To get from the bus stop to the workplace door, must the transit passenger walk across a huge parking lot while dodging cars, as in so many campus-style office parks, or is the workplace entrance located near the bus stop with a sidewalk for access, as in a more pedestrian-friendly downtown? For how many households or employees is transit service within 5 minutes, 10 minutes, 15 minutes, or more by foot? Conventional model data structures are usually unsuited to determining even weighted averages of such parameters and if such parameters are used, they depend on the crude guesswork of semi-skilled planning technicians and interns who do much of the laborious network coding.

Fine-grained networks of footpaths, sidewalks, bikeways, alleys, and neighborhood streets are found in virtually all human-scale livable cities of the world and are essential for the transportation, community access, and connectivity functions they perform, but these are usually neglected in conventional aggregate zone-based transportation model systems. Until recently, the costs of collecting, coding, storing, and using such data within regional computer transportation models have been excessive. Roads and bus and rail lines are the sole representative elements of transportation capacity in most conventional zone-based regional transportation models.

The overuse of such transportation models to set priorities for transportation capital investment and operations planning in the United States, despite their inability to simulate short trips, non-motorized trips by foot or bicycle, and access trips to and from public transportation, has led to neglect of these elements of the mobility system. This practice has shaped the design of modern automobile-dominated American suburbs. Aggregate models have been used to justify creation of a built environment that encourages all who can to maintain a fleet of several cars per household to avoid immobility.

There has been an overreliance on area-specific calibration factors in conventional regional transportation models in the United States and in Montgomery County, Maryland, which has relied mostly on models developed by COG for the region. These factors have allowed models to calibrate to observed data without attaining sensitivity to key factors that account for differences in travel behavior, such as the quality of the pedestrian environment or the age and density of the neighborhood.

As communities mature from new neighborhoods to older neighborhoods, they frequently become far more demographically diverse. The degree of diversity shapes key elements of travel behavior, especially in the diurnal distribution of trips. Yet area-based factors in models mask these differences and rule out forecasting possibilities for change in the orientation of mobility systems in newer communities. With such factors, models become almost circular in their logic and make it nearly impossible to simulate the future as anything other than an intensified image of the present.

This is often reinforced by the tendency of conventional models to deal with households and employment in isolation as unitary input quantities. The models do not ask how these jobs and households are mixed at a small scale. Are there apartments over stores in the fashion of Europe, Japan, and America before the automobile age or are all the uses segregated in mid- and late-twentieth century fashion? The models usually do not ask how expensive are the dwellings and how much do the jobs pay? Can all the people who work in the jobs afford to live nearby? At what stage in their life-cycle are the households in each neighborhood? These questions lie at the current frontiers of computer transportation modeling, which must begin to incorporate activity analysis principles and textural variables into model structures to improve model stability and explanatory power over longer time frames.

The M-NCPPC hopes to use GIS technology and improved data acquisition and management systems to begin to get cost-effective quantitative answers to such questions so that computer transportation models can reflect more of the richness of the reality that shapes traveler behavior, mode choice, and community structure. GIS software can manage and manipulate spatially detailed data structures useful for describing trip origin or destination characteristics as thousands of points rather than as hundreds of zones, and may find an important role in trip generation and mode choice modeling. Conventional zone-based transportation models, however, retain their strength in the manipulation of two and three dimensional matrix data, such as trip distribution and trip-table development, and in network assignment and analysis.

Montgomery County planners are just beginning to explore these opportunities. Work is getting underway in 1990 to recalibrate the M-NCPPC travel demand models with the objective of eliminating as much as possible the use of area-specific model coefficients.

USE OF GIS SOFTWARE WITH TRANSPORTATION MODELS

Like a number of other planning agencies in fast-growing areas of the developed world, the M-NCPPC is exploring linkages of GIS to transportation and other modeling. The first M-NCPPC Montgomery County Transportation Division use of GIS software is for acquisition of more refined land use and demographic data at traffic zone and subzone levels from county tax assessor parcel file records, household and employment surveys, and other sources. The GIS should provide better data for transportation model input and calibration and aid the display of zone and network data inputs and outputs related to the model system.

The use of parcel file records to allocate zone level land use data to subzones for input to fine-grained model systems will be tested in early 1990. This application may allow substantial improvement in the productivity of planners producing land use data inputs for these subarea master planning models. Other applications are expected in the near future. The combination of SPANS and EMME/2 may allow greater sensitivity of the models to transit serviceability and other small scale factors in the built environment that affect travel behavior. SPANS may aid refined spatial analysis of travel survey data and, as a GIS data base integrator, it may aid low-cost data acquisition for developing a superregional Baltimore-Washington transportation model focused on Montgomery County, which sits between these two major cities.

Eventually, combining GIS technology with conventional transportation models may make it possible to overcome many problems inherent in aggregate zone-based model structures where the variance in data within zones exceeds the variance between zones. Highly disaggregate analysis of origin and destination characteristics related to trip generation and mode choice can be accomplished in the GIS environment, using point-based data, that can then be summarized or stratified for use in conventional zone-based software, such as EMME/2. Zone-based software has great strengths in manipulation of full matrix and network-related data.

One of the challenges of developing subarea models is to generate input—land use forecast data for small subzones. The M-NCPPC participates in the COG cooperative forecast process and develops forecasts of housing and employment by type for each of the 246 traffic zones used by the M-NCPPC regional model, for each 5-year interval out to the year 2010. These forecasts, while far from perfect, serve as reasonable indicators of possible future development patterns, given current market trends, zoning, and demographics. Until now, however, the only way that land use could be developed for subzones was by tedious hand mapping and calculation by a small team of community planners who would draw upon a number of data sources to "add up" the elements contributing to growth within each subzone.

Now with a GIS, these planners are poised to gain more freedom to think more about what direction they might like to push the zoning and development of the areas they are master planning with less time required for the mechanics of the process. The GIS can add up the elements desired by the planners through simple map overlays and the generation of unique condition reports for each subzone, zone, or geographic entity of interest. The procedure developed enables the direct calculation of subzone level totals from a disaggregate map layer or the allocation of zone-level forecast data to subzones on the basis of weights developed as a function of other map levels, with various boundary and control conditions on the allocation to ensure consistency and common sense. Typical input data include:

- The 255,000-record tax assessor parcel file containing data on all registered land parcels in the county, including acreage, zoning category, land use codes, assessed value of land and buildings, and numerous geographic tags, such as traffic zone number and census tract and block.
- A data attribute file concerning all approved subdivisions in the county, including information on size of approved subdivisions.
- Vector line graph files of parcel boundaries for approved subdivisions that can be polygonized.
- Vector line graph files of zone and subzone boundaries that can be polygonized.
- Attribute files of any type for policy areas, zones, subzones, parcels, or other areas that can be defined as polygons, such as areas within one-half mile radius of transit stations.

Numerous decision rules can be developed and applied within this general methodology. Currently the process requires a number of manual steps by someone skilled at using GIS software and some relatively simple custom software for processing the data base after using the GIS. Development of more automated procedures for accomplishing this methodology is underway.

GROWTH MANAGEMENT APPLICATIONS OF THE MONTGOMERY COUNTY MODEL

Annual Growth Policy

The M-NCPPC AM peak-hour model was first used in late 1987 to evaluate the annual growth policy limits on subdivision approvals. The new model, as one might expect, showed that traffic congestion would be worse in the low-density, sprawled new suburban growth areas than previously thought and somewhat better than previously thought in the higher-density inner-ring suburban centers.

Montgomery County's growth policy controls how many houses and jobs can be approved as new subdivisions of land in about 20 policy areas of the county. Because it takes some years to build these subdivisions, there has been much debate about what programmed road capacity should be considered available to support these subdivision approvals. Currently roads must be 100 percent funded within the next four years to be counted as available for the growth policy analysis.

Staff and M-NCPPC planning board recommendations of growth policy limits and administrative procedures are reviewed, guided, and adopted by the Montgomery County Council. Growth policy limits in Montgomery County are set by evaluating anticipated future traffic congestion levels against level of service standards describing acceptable traffic congestion levels for each policy area. More congestion is deemed acceptable in areas that have greater transit availability and where people thus have greater choice about how they can travel to work (*4*).

The growth policy limits are set through a judgmental evaluation of model outputs, not by any automatic process. Under- and oversimulation, observed differences between AM and PM peak hour conditions, and other technical adjustments must be made to interpret model outputs recognizing the weaknesses of the modeling system. To take back already approved subdivisions is almost impossible. Generally, county planners have made adjustments to job or housing growth limits only in those policy areas where new transportation capacity has come on line in a new budget, although periodic adjustments to account for trip distribution changes and improvements in the measurement and simulation of traffic levels of service are now being considered.

Thus, the result of changes from a daily to AM peak-hour model has only slowly taken effect in growth policy administration, as changes in transportation capacity, policy area boundaries, level of service standards, and other factors make it possible to alter growth limits established within a complex growth policy system.

In the coming months, the staff hopes to use GIS software to analyze proposed new policy area boundary definitions and use the logit model and transit network descriptions to devise improved measures of transit availability related to setting acceptable traffic congestion level of service standards for policy areas.

General Plan Assessment Study

In 1987, the M-NCPPC used the EMME/2 model system for the first time for long-range planning in a sketch planning exercise that evaluated the Montgomery County general plan (5). At the time, the new M-NCPPC logit model had not yet been developed, so default mode shares from some long-range modeling done by the Council of Governments, at times modified judgmentally using various techniques, were used to convert person-work trips to auto driver-work trips.

In an initial scenario, it was assumed that the entire zoning capacity of the county was built out along with the entire master plan of highways and transportation. This initial scenario produced extremely high levels of road congestion everywhere in the county, even with some increase assumed in transit mode share, and led to the conclusion that the county was overzoned for employment relative to housing.

Another scenario was developed in which the number of jobs was reduced by one-half. Without major changes in work trip mode shares, however, it was clear that even this would produce excessive traffic congestion.

This scenario was then modified further by assuming a regional network of light rail lines, amounting to 65 miles (100 km) in Montgomery County alone, that would connect all major activity centers in the polycentric Washington, D.C., region to each other and to the region's 103 mile (163 km) Metro system. It was also assumed that other public policies supportive of walking, bicycling, and public transport would be adopted. This scenario included a circumferential light rail network around the region roughly paralleling the Capital Beltway to help alleviate traffic pressures on that road, measures to slow and calm traffic in major growth centers to improve pedestrian and cyclist conditions, and major investment in sidewalks and bicycle paths.

EMME/2's matrix calculator was used to perform a thoughtful, largely judgmental manipulation of COG forecast mode shares on a zone pair specific basis to reflect these assumptions. This led to a reduction in anticipated county-wide origin automobile driver mode shares for work trips from 78 percent in 1987 to an assumed 50 percent. This "fewer jobs, enhanced transit" scenarios showed promise of achieving traffic congestion levels close to the standards set under the county's Adequate Public Facilities Ordinance.

This analysis was presented to the County Council in early 1988 and influenced a major zoning text amendment that had the effect of reducing employment zoning capacity in the county by roughly one-third in early 1989. The council also provided the M-NCPPC with $250,000 for further work, titled the Comprehensive Growth Policy Study (CGPS) (*6*).

Comprehensive Growth Policy Study

The CGPS, released in July 1989, looked 30 years into the future at the tough choices the county might face in balancing job and housing growth with attendant demands for transportation and schools, focusing particularly on fiscal and traffic congestion impacts. The study developed and evaluated land use and mobility patterns with appropriate bundles of supporting public policies consistent with each scenario.

Four major land use scenarios were devised with different levels of housing and jobs—FAST but balanced growth, SLOW but balanced growth, JOBS favoring employment growth, and HOUSING favoring housing growth. These were tested against several mobility patterns—AUTO continuing current policies and building out the master plan of highways, VAN adding to this a network of high occupancy vehicle lanes, and RAIL adding to AUTO a light rail network similar to the one described for the General Plan Assessment Study. For the RAIL pattern, most new housing and job growth above current levels of approved development were clustered at higher densities near rail stations. For the VAN pattern, the clustered employment pattern developed for the RAIL pattern was retained but the more sprawled housing of the AUTO pattern based on current zoning was used.

Major advances were made in techniques to develop alternative zone-level land use scenarios, working from the bottom-up to take account of community design principles, from the top-down to take account of knowledge gained through annual growth policy model analyses, and using in-house computer software to all-the-while observe a host of complex decision rules to ensure that the resulting land use allocations respected various boundary conditions at zone and countywide levels. For the analysis, the county's 246 zones were split to 285 to allow greater detail in the areas with potential to become higher-density, new town centers.

In addition, the RAIL pattern assumed that:

- Major investments would be made to make all major activity centers very pedestrian- and bicycle-friendly, with measures taken to slow and calm automobile traffic in these centers,
- Transit-serviceable site planning would be adopted countywide, moving away from sprawled campus-style office development and homogeneous development,

- Parking charges would be much higher than today in all employment areas and parking supply would be capped in central business districts,
- An ordinance would be passed to require equalization of commuter subsidies, reducing user-perceived public transport fares, and
- Gasoline taxes and registration fees or road pricing would effectively double the cost of automobile operation.

The VAN pattern assumed a more modest package of supportive public policies. Figure 2 shows the mode shares obtained using the M-NCPPC nested logit mode choice model with these assumptions.

This model analysis used somewhat more sophisticated models and more refined input data, but was fundamentally consistent with the earlier sketch-level analysis in its conclusions. Figure 3 shows one of the major summaries of the study, comparing the auto driver-work trip mode share with the average traffic congestion level, countywide.

It is clear that the AUTO pattern—continued dependency on the automobile as the prime element for mobility—does not work from a transportation (or environmental) standpoint, regardless of the land use assumed. The VAN pattern fares considerably better, and reduces the congestion level closer to the countywide standard, but still fails for the FAST quantity of jobs and households. It might work for lower levels that were not tested due to time constraints. The RAIL pattern allows the county to closely approach or meet its traffic congestion standards, depending on the land use balance between housing and jobs.

If all else is held constant in the RAIL FAST scenario, but more housing is clustered in the inner ring and core of the region along the Metro lines, in a scenario variant called RECENTRALIZATION, traffic congestion levels in Montgomery County fall significantly. This scenario would tend to have the lowest per capita energy use, air pollution, and infrastructure costs as well, but is politically problematic for a variety of reasons. However, it points up the benefits of containing sprawl, developing real town centers and more affordable housing near jobs, with housing and jobs clustered near good public transportation in pedestrian- and bicycle-friendly areas, and encouraging reinvestment in housing in and near the central city.

The findings of the CGPS have added to the pressure for significant changes in the direction of master plan development, growth management, and the update of the county

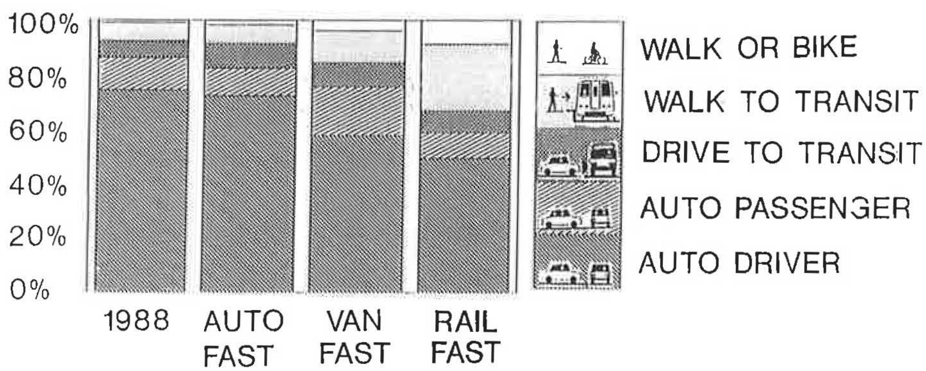

FIGURE 2 Montgomery County origin model share for home to work trips.

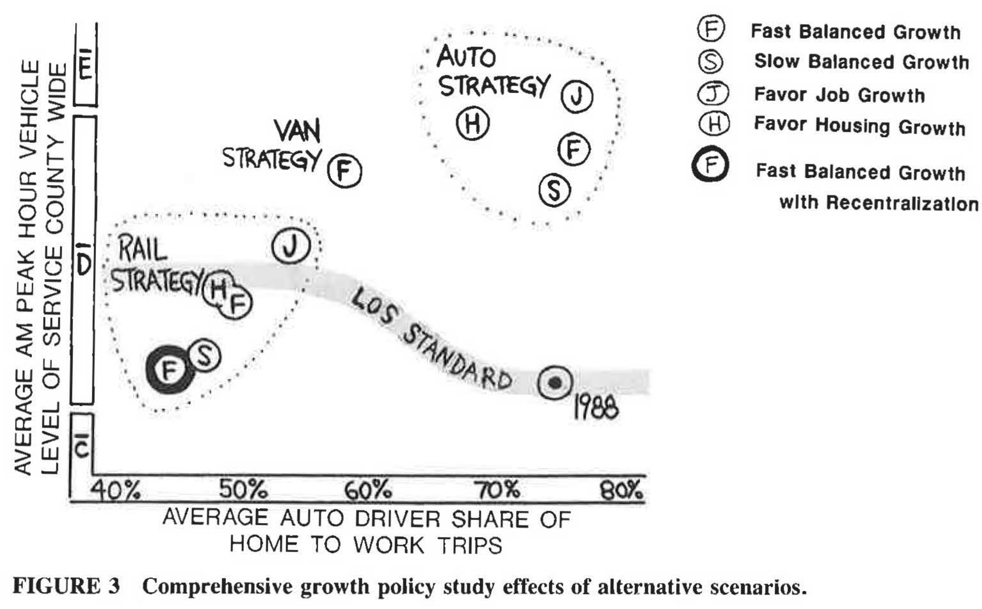

FIGURE 3 Comprehensive growth policy study effects of alternative scenarios.

master plan of transportation. It remains to be seen with what speed these reforms will take root, as they challenge many standard practices and vested interests. However, as the county faces a growing fiscal crisis, increased traffic problems, an affordable housing and labor shortage, and growing environmental problems, the CGPS suggests ways of making growth both economically and environmentally sustainable. The CGPS is expected to form a foundation for much planning in the county in coming decades.

CONCLUSIONS

It has become essential for United States local governments to develop new ways of evaluating transport and land use public policy options and alternatives to the single passenger automobile. These evaluation systems must be capable of testing the impacts of moving towards more clustered mixed-use development patterns and significant mode shifts away from the automobile, if growth is to be made economically and environmentally sustainable. Computer transportation models, GIS, and data management systems are all important tools for such work. Local governments must move quickly to adopt these tools and to train and retain qualified staff to manage them if they hope to manage growth effectively.

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