Super-Regional, Very Long Range Transportation Modeling with a Geographic Information System

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An application is presented of a geographic-information-system (GIS)-based modeling system to a regional transportation problem in the greater Charlotte, North Carolina, area, specifically an evaluation of a proposed super ring road around the region called the "Carolinas Parkway." The use of a GIS, in conjunction with the transportation modeling system, allowed for a fairly complete analysis of a very long range transportation proposal to be evaluated at the super-regional scale. Basically, the GIS system allowed the analysis to be completed in a short period of time with a minimum of complexity. However, software limitations and compatibility issues reduced the overall effectiveness of the effort. In summary, transportation planners and analysts in super-regional environments are encouraged to look carefully at geographic information systems, particularly those blended with transportation models, as a means to facilitate and encourage coordination and cooperation. In the future, more sophisticated models will be required if GIS-Ts are to be fully usable.

So called "super-regions" are large metropolitan areas consisting of one or more substantial urbanized areas surrounded by smaller cities and communities. These areas typically are between 80 and 160 km (50 and 100 mi) across and are extensively connected by Interstate and other high-speed road systems. Their primary spatial feature is that they operate economically as a single unit. Within super-regions, complex travel patterns between and around the individual metropolitan core areas are involved.

The concept of super-regions in the United States is not new. As early as the 1960s, Jean Guttman identified "megalopolis" structures in the northeast corridor of the country. Since that time, numerous super-regions have emerged, largely through the interconnection of several metropolitan areas and their surrounding smaller cities. In the Carolinas, a number of super-regions have emerged in the last two decades. Primary among these are the Raleigh–Durham–Chapel Hill research triangle area, the Greensboro–Winston Salem–High Point "triad" area, and the greater Charlotte metropolitan area. Each of these regions contains one or more major cities and other cities that were historically isolated economic communities, but have now grown together and become integrated economically.

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In super-regions, services like transportation are extremely complex and difficult to provide. In the greater Charlotte metropolitan region, for instance, the surrounding 13-county metropolitan area has five metropolitan planning organizations (MPOs), more than 40 towns and country government organizations, and two state highway departments, all of which are responsible for various aspects of transportation planning and investment (Figure 1). These organizations are not generally contiguous, and consolidation or cooperation is not legally required. Each agency had its own procedures and methods for undertaking transportation planning and, until recently, treated the other cities and communities of the region as "external," both politically and technically. Not surprisingly, the result was fragmented planning with largely incompatible analytical methods, survey procedures, and, occasionally, philosophies. Separate transportation plans for many areas were developed somewhat independently. The result has been that coordination and cooperative planning for transportation, which is so essential for making progress an intraregional travel, is very difficult.

Three important recent developments have helped to remove these impediments. First, in many areas, including Charlotte, regional organizations such as the Carolinas Transportation Compact (CTC) and COGs have opened channels for communication (*1*). Second, rapid diffusion of microcomputer transportation planning software has allowed many small areas within regions to model and analyze traffic. The resulting diffusion of information is not nearly as important as the diffusion of power that this new technology provides (*2*). Recent Intermodal Surface Transportation Efficiency Act legislation and Clean Act Amendments encourage or require adjacent areas to coordinate regional transportation matters.

Third, geographic information systems (GISs), which automated procedures that store, collect, analyze, and interpret the geography of regions on a large scale, have been developed. GISs evolved from land-use planning systems in the 1970s, but they now contain many analytical and modeling procedures that permit problems such as transportation to be studied. GIS technology has recently been merged with microcomputer transportation software technology (GIS-T). One commonly used package, TransCAD, is a combination of GIS and transportation models that allows transportation planners to easily analyze integrated regional transportation systems.

The number of applications of GIS-T procedures has increased rapidly in the past 5 years. Initially, GIS was used primarily to analyze site and corridor transportation alternatives, that is, storing, gathering, and displaying informa-

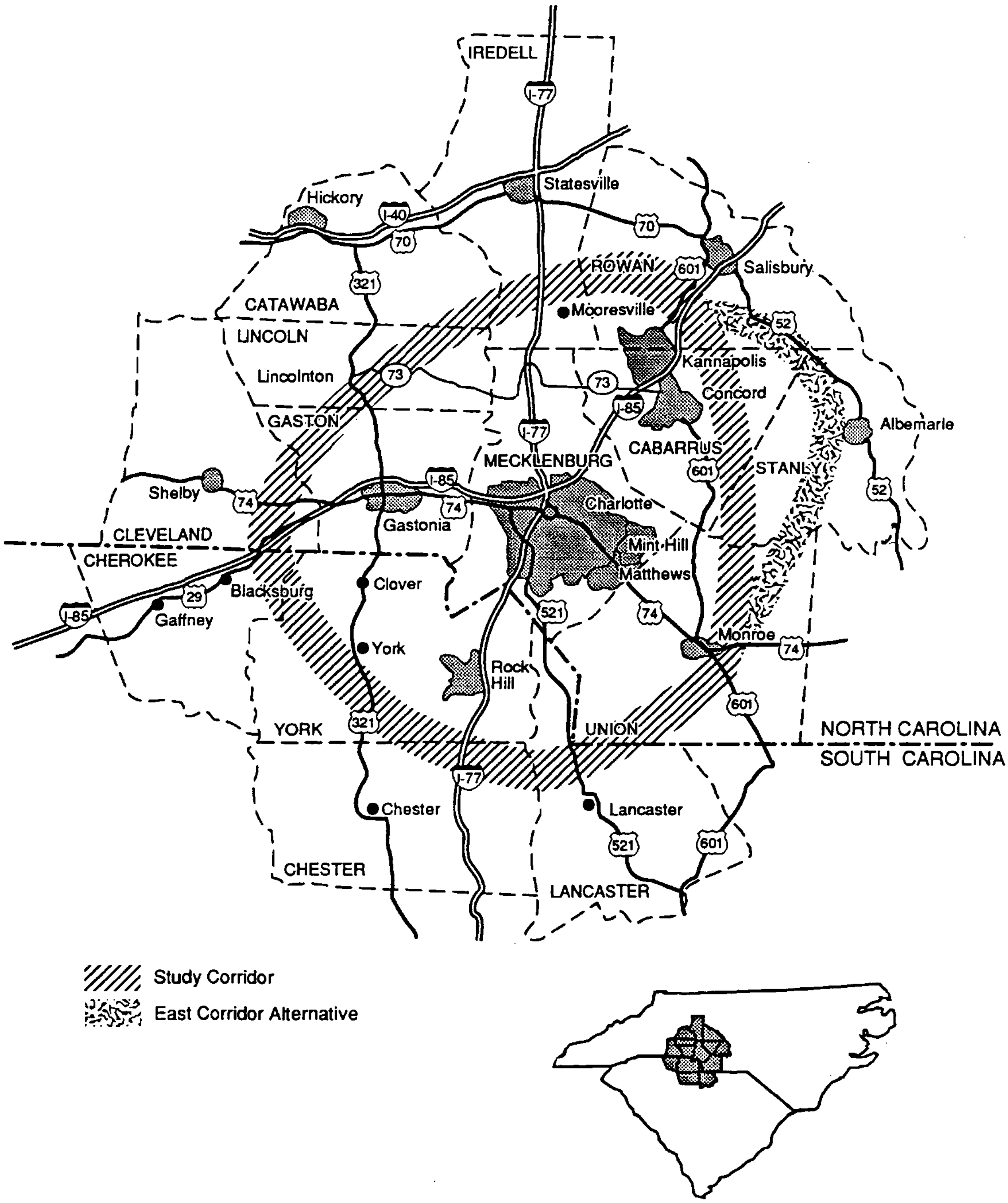

FIGURE 1 Charlotte metro region.

tion. Data related to modeling was "transported" from other systems into the GIS for display purposes (*3*). Examples of these applications include studies in Dallas and northern Virginia (*4*). A recent application at the University of North Carolina at Charlotte (UNCC) involved developing noise contours along roads to isolated parcels that may be suitable for industrial development as opposed to residential development (*5*). More recently, virtual reality applications of GIS have been applied in transportation, particularly for simulating driving along planned roads. Parsons Brinckerhoff, for instance, used this methodology to develop a view of how a new road proposal in Tennessee would fit within the landscape (*6*). The number of modeling applications in which transportation forecasting models have been embedded within GISs is also increasing. Most of these applications use either a GIS tied to microcomputer model (*7,8*) or a specialized GIS software package, such as TransCAD, because commonly available GISs, such as ARC/INFO, do not have extensive transportation modeling capability. Applications of traditional urban transportation planning system (UTPS) type models using GIS are reported for the Charlotte area (*2*), outlying communities of Philadelphia, and a number of other cities (*9*). In addition, GIS applications to larger-scale problems, such as states and the United States as a whole, have also begun.

This paper describes a process by which GIS-T procedures were applied to a very long range regional transportation proposal in the greater Charlotte, North Carolina, area, specifically an evaluation of the proposed super ring road around the region called the Carolinas Parkway. The basic theme of the paper is that the use of a GIS, in conjunction with the transportation modeling system, permitted a preliminary analysis of the transportation proposal in a short period of time with minimal complexity. This paper will focus on the use of this GIS-T and its limitations, not the evaluation of alternatives. The reader is referred to technical reports of the study (*10–12*) for this information.

GIS MODELING APPLICATION: CAROLINAS PARKWAY

Carolinas Parkway and Charlotte Region

The Carolinas Parkway, a proposed outer ring road for the Charlotte region, is envisioned as a limited access road at a distance of about 32–65 km (20–40 mi) from Charlotte. The ring road is designed to link I-77, I-85, and other radial highways (Figures 1 and 2). The Carolinas Parkway concept was developed by the Carolinas Transportation Compact (*13*) as part of a 50-year long-range transportation "vision" effort. Its function would be to coordinate land use and transportation planning, which is viewed as necessary to create an attractive, efficient regional transportation system that will also support economic development objectives.

As a result of dialog between state and county agencies and the CTC, it was agreed that the Carolinas Parkway concept should be tested to determine the travel efficiency and benefit it might contribute to the region's transportation system. Parsons Brinckerhoff Quade & Douglas, Inc., supported by UNCC's Center for Interdisciplinary Transportation Studies, conducted the traffic forecasting using a GIS-based travel forecasting package, TransCAD. Phase 1 was designed to focus on assessing the feasibility of the parkway by determining its potential for generating regional travel benefits over a 20-year period (2010 to 2030). It included the generation of socioeconomic forecasts, estimates of future travel characteristics, and a feasibility assessment that focused on environmental impact issues and parkway cost. Phase 2 was designed to focus on optimizing the parkway location, examining partial ring road concepts, and identifying other needed highway improvements.

Model Overview

The TransCAD modeling system consists of a personal-computer-based GIS augmented with numerous procedures

FIGURE 2 Regional network and Carolinas Parkway alternatives.

for transportation modeling. The GIS portion contains the usual features and capabilities:

- Layers
  - Points (cities, nodes),
  - Areas (zones, tracts, counties), and
  - Lines (street links);
- GIS Capabilities
  - Data capture, such as digitizing (digitizer or mouse) or worksheet data,
  - Data storage and retrieval (data editor to store display and update attribute data),
  - Information query (query on certain features on screen or by conditions),
  - Display of selected features and layers, such as band width, color, labels, and theme map,
  - Spatial analysis (overlay polygons, generate buffer zones, statistics), and
  - Cartographic products, such as thematic maps.

The regional transportation forecasting model used in this study may be thought of as a simplified traditional UTPS model. It consists of a simplified gravity modeling procedure using only one trip purpose, supported by a number of assignment capabilities. Trip ends to drive the model were developed from population and employment statistics in a spreadsheet application, Microsoft Excel. The trips were then loaded into TransCAD, directly to the loading nodes, which in this case are intersections on a sketch regional network about 160 km (100 mi) across. There is no zone structure required, as is common for other packages. The network also contained future road proposals, both those on the transportation improvement plan (TIP) and those in the various long-range plans of the counties and cities in the region. In this case, travel was assigned to the network using an all-or-nothing methodology, without capacity restraint. This is necessary because the regional network is a sketch network that does not contain all roads.

The model is calibrated by comparing estimated daily traffic and observed data on the sketch network street system and then adjusting the beta value—the empirical parameter for the friction factor in the trip distribution model. After overall network performance is achieved, remaining differences between estimated and actual traffic are "pivot points" into the future and applied to future projections.

When using a GIS to conduct transportation modeling, early decisions on totals and details are critical. Essentially, the analyst is balancing complexity and detail with the needed output accuracy. More accuracy takes more time to calibrate and forecast, but it is not needed if the study horizon is very long range (30-plus years) or if the geography is to be highly aggregated. The authors' application of the GIS is for a sketch model, highly idealized and very long range, so many details that would be needed in other models (i.e., multiple-trip purposes, trip length distribution checking, link-level calibration accuracy) are unnecessary.

Base Network

The GIS features of TransCAD, particularly the link and node layers, facilitate sketch-level network preparation. To begin this study, a national network of major Interstate and primary routes was obtained from the vendor. This network showed major intersections, but not enough of the road system, not even for sketch modeling. To augment this network, additional routes were coded to represent major streets and county roads, but not all collector streets or parcel-access roads.

The base network link information includes length, speed, number of lanes, capacity, and base year (1989) traffic counts. The travel time was calculated using a delay penalty developed and tested by UNCC's earlier study (*2*). This penalty, a function of link length and road type, slows down the network to account for missing nodes and congestion. It, therefore, approximates more complex features such as capacity-restrained assignments.

Base-year trip ends were generated based on the socioeconomic data in the region. The 1988–1989 population estimates from U.S. Census data and the 1989 retail and nonretail employment data at ZIP-code zone level were used to generate trip productions and attractions. Rather than use the "traffic analysis zone" method to locate the population and employment data, the data were directly tied to selected loading nodes on the network (*2*). Vehicle trip ends were derived from dwelling units, retain employment, and nonretail employment according to the procedures in Table 3 of *NCHRP Report 187* (*14*). It should be noted that a deduction factor of 0.721 was applied to the trip ends, because about 28 percent of the vehicle miles traveled (VMT) in the region is on the local network, which was not coded in the network (*15*). Productions and attractions on external stations were set to half of the annual average daily traffic (AADT) volume on each external link, assuming that all nodes on the edge of the region were loading nodes that had both productions and attractions. This ensures the balance for external nodes.

This approach is highly simplified compared with typical UTPS modeling but takes advantage of GIS' integration features. By using *NCHRP Report 187* and its rates, the authors assumed constant trips per household or worker. If the rates per household increased (and these rates generally did not, rates per person did), then the method would underestimate future traffic. By using a reduction factor, the authors assumed a constant ratio of travel on high and low facilities. While these ratios may be different in the future, the authors had no basis for changing them. A better procedure, the authors believe, would be to use this GIS-T to test many futures instead of trying to detail a few. This is the essence of sketch playing with a GIS-T: use speed and flexibility to understand broad implications quickly instead of using computer power and detail to "over-describe" hypotheses.

Calibration

The regional model was calibrated by comparing the traffic generated by the model with real observed AADT on the same base network. Because of the large scale of the regional model, traffic counts were used instead of a trip length distribution. This method is typically necessary in super-regional modeling because the super-region does not have an integrated travel survey. Also, TransCAD does not have a trip length distribution or friction-factor calibration procedure. The deviations of AADT, vehicle hours traveled (VHT), and

VMT from the actual data were summarized by link type, county, region, and screenlines; this assisted the evaluation of model simulation accuracy. The model was gradually improved by adjusting the beta value for the friction factor in the gravity model, travel time penalties by link type, and travel time impedance values for a few individual links. Overall regional average trip length and county-to-county flow patterns were also carefully checked. Screenline changes throughout the area were also used for accuracy checks.

There are four basic methods of assignment in general use: minimum path, capacity restraint, equilibrium assignment, and stochastic assignment. In the minimum path (all-or-nothing) method, the traffic flows for each origin-destination (O-D) pair is assigned the single minimum cost path, without taking into account congestion conditions. The capacity restraint method, on the other hand, considers capacity by recalculating the link costs at each iteration of all-or-nothing assignments. This procedure allows the traffic to spread out incrementally to other street routes. The third method, user equilibrium assignment, produces an exact solution that has the property that no travel can change routes without increasing the travel time (i.e., the traveler's presence slows all traffic). This method not only spreads out the traffic, but also typically results in higher VHT and VMT for a given network and O-D pattern. The fourth method, stochastic assignment, assigns trips to paths randomly, thereby more closely approximately user uncertainty.

In the TransCAD system, several assignment procedures are available. The choice, however, is not trivial because the accuracy of the forecast depends on network diversity. The more sophisticated procedures are commonly used when (a) full set of trip purpose data is available and (b) network detail permits alternate paths to be chosen. In this study, a sketch network for long-range planning is used, and overall effects rather than minor ones are considered. Therefore, the all-or-nothing traffic assignment method was adopted for traffic calibration and forecasting. This procedure will have the effect of making the parkway forecasts somewhat higher than that with a capacity-restrained forecast.

However, the base-year accuracy of the calibrated model was checked by calculating the percentage of deviation of the average daily traffic (ADT) estimated by the model against the actual 1989 ADT counts (*2*). The acceptable deviation ranges for different ADT volume ranges were defined according to *NCHRP Report 255* (*16*). Over a series of about 25 trials, it was possible to bring the overall estimated regional VMT to ± 1 percent of actual VMT. The final model passed calibration tests recommended by FHWA (*17*).

The best calibration will not produce perfect agreement between estimated and actual traffic. Because there are deviations between the actual counts and the volumes estimated by the calibrated model, some adjustment will always need to be made to the forecasts. Pivot-point methods were calculated for each link, as follows:

$$\text{Pivot point} = \text{ADT/EADT} \tag{1}$$

where ADT is the actual ADT in base year and EADT is the estimated ADT in base year, by using the traffic simulation model.

Then in forecasting, it is assumed that

$$\text{ADT}_f = \text{EADT}_f * (\text{ADT/EADT}) \tag{2}$$

where ADT_f is the future actual ADT and EADT_f is the future EADT.

The pivot-point values are used as an adjusting factor for the future traffic forecasts; they are not used in calibration. The forecast ADT of a link can then be obtained by multiplying the estimated future ADT by the pivot point for that link. This procedure accounts for the difference in base assignments and base ADT for future forecasts, thereby producing a better future estimate. The method is fully described by Pederson and Samdahl (*16*). While it may appear to be a "hard-wire" adjustment, note that these adjustments are applied only after the overall model is accurately calculated and that the method uses additional data (base-year ADT counts) that otherwise would be discarded.

Use of the GIS greatly facilitates calibration. The ability to display data on individual links (especially, estimated versus actual ADT, on volume-to-capacity (V/C) ratios) along with zonal and loading node information, permits rapid detection of errors and a clear, broad view of the entire system's performance by area or facility type.

Forecasts

For traffic forecasts, the road network was expanded by the addition of planned roads in the formalized TIP and long-range thoroughfare plans. Two future Carolinas Parkway networks—2010 and 2030—were analyzed.

Regional socioeconomic forecasts were prepared using the unit of U.S. Census tracts to forecast households and retail and nonretail employment for the Charlotte super-region. These tract forecasts were then "attached" to existing network loading nodes, by identifying one or more nodes in each tract (Figure 3 shows the census tracts and the loading nodes in the region). Socioeconomic forecasts were prepared for two scenarios: a "low" parkway influence and a "high" parkway influence. These two scenarios were evaluated to determine the sensitivity of the potential parkway travel benefits to different development patterns. Data for the two scenarios were converted to trip productions and attractions in terms of the same methods used in the calibrated model. Also, the same deduction factor of 0.721 was applied to the future trip ends for the sketch network effects. Forecasts were prepared for years 2010 (the assumed year that the parkway opens) and 2030 (20 years after the parkway opens). The GIS structure for counties and census tracts was used to display forecasts. The technical report (*12*) details the results.

Future external productions and attractions were factored by the growth rates. The growth rates used are as follows:

	1989–2010 (%)	*1989–2030 (%)*
Interstates	31.5	61.5
Other roads	25.2	49.2

These factors were applied on base-year productions and attractions at the external stations to generate 2010 and 2030 Ps and As. The GIS was used to store and manipulate the production and attractions and to ensure the overall regional

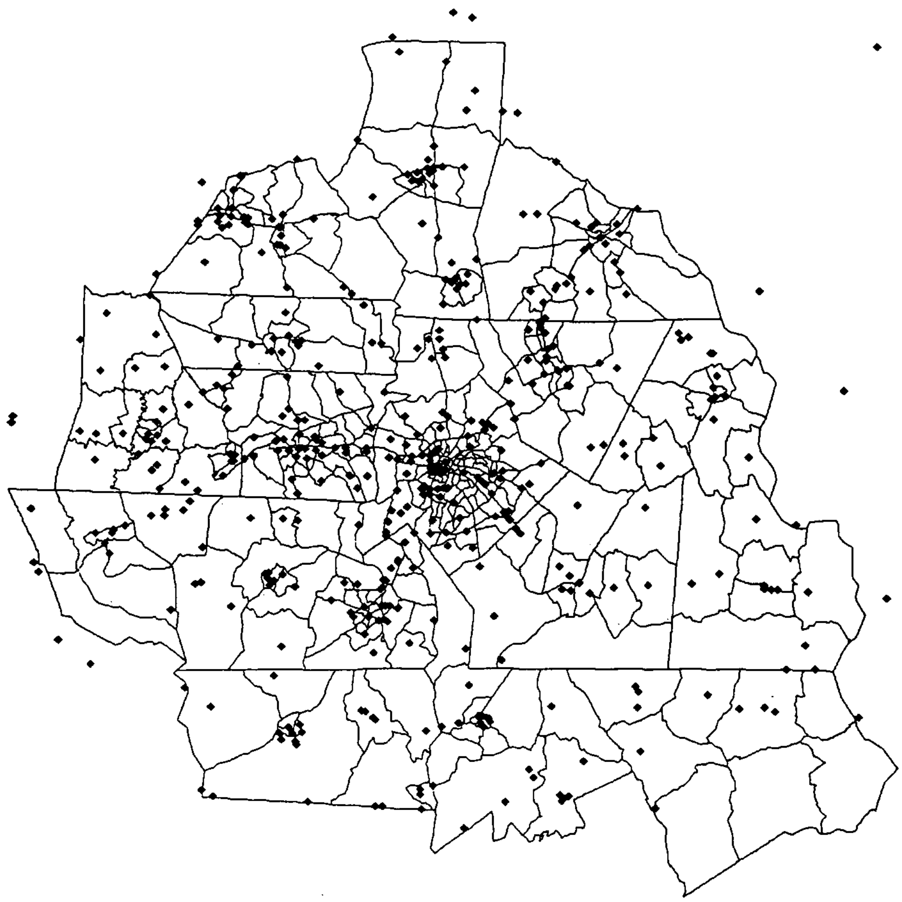

FIGURE 3 Census tracts and loading nodes in region.

balance. Figure 4 is an example of trip ends loaded into the modeling system.

To test the impacts of the parkway, seven all-or-nothing assignments were prepared:

1. 2010 low influence, no parkway build scenario,
2. 2010 low influence scenario (build),
3. 2010 high influence scenario (build),
4. 2030 low influence, no parkway build scenario,
5. 2030 low influence scenario (build),
6. 2030 high influence scenario (build), and
7. 2030 high influence (build), with parkway eastern alternative.

The raw results of each assignment were adjusted by multiplying forecast volumes by pivot points gained from model calibration. A few pivot points were manually adjusted after analyzing the results to ensure a smooth traffic pattern. Figure 5 shows the traffic volumes on the parkway for 2030 high influence scenarios by bandwidth. Traffic forecasts for the parkway alternatives would seem to be clearly into the four-lane range for both the time frames. Overall traffic volumes on the Carolinas Parkway are substantial.

The analyses and displays of assignment results relied largely on the GIS. Forecasts for each assignment were stored automatically in the GIS by the link, where it is a simple matter to show the percentage of change or ratios to the base-year traffic. Several comparative analyses were made showing traffic on key road segments in the region. The general comparative tables for the regional VMT, speed, VHT, and emissions were also developed. The GIS was found to be particularly useful in showing changes in volumes on local roads with or without the parkway in rapid fashion. Thus, a visual perception for the parkway's impacts was quickly developed.

Feasibility Analysis

The feasibility of the parkway was determined by comparing the estimated user benefits of the project with the estimated construction costs. A procedure and corresponding computer models developed by the North Carolina Department of Transportation (NCDOT) were used for the calculations. User benefits is one component of the benefits matrix model, which also includes project costs, economic development potential, environmental impacts, and the relationship of the project to the state arterial system. The model is used to set priorities for urban highway improvement projects for funding. User benefits were calculated as the difference in regional highway user costs between the no-build scenario and the parkway scenarios. The user costs calculated were vehicle operating costs, travel time costs, and accident costs. These findings are reported in the technical studies (*12*).

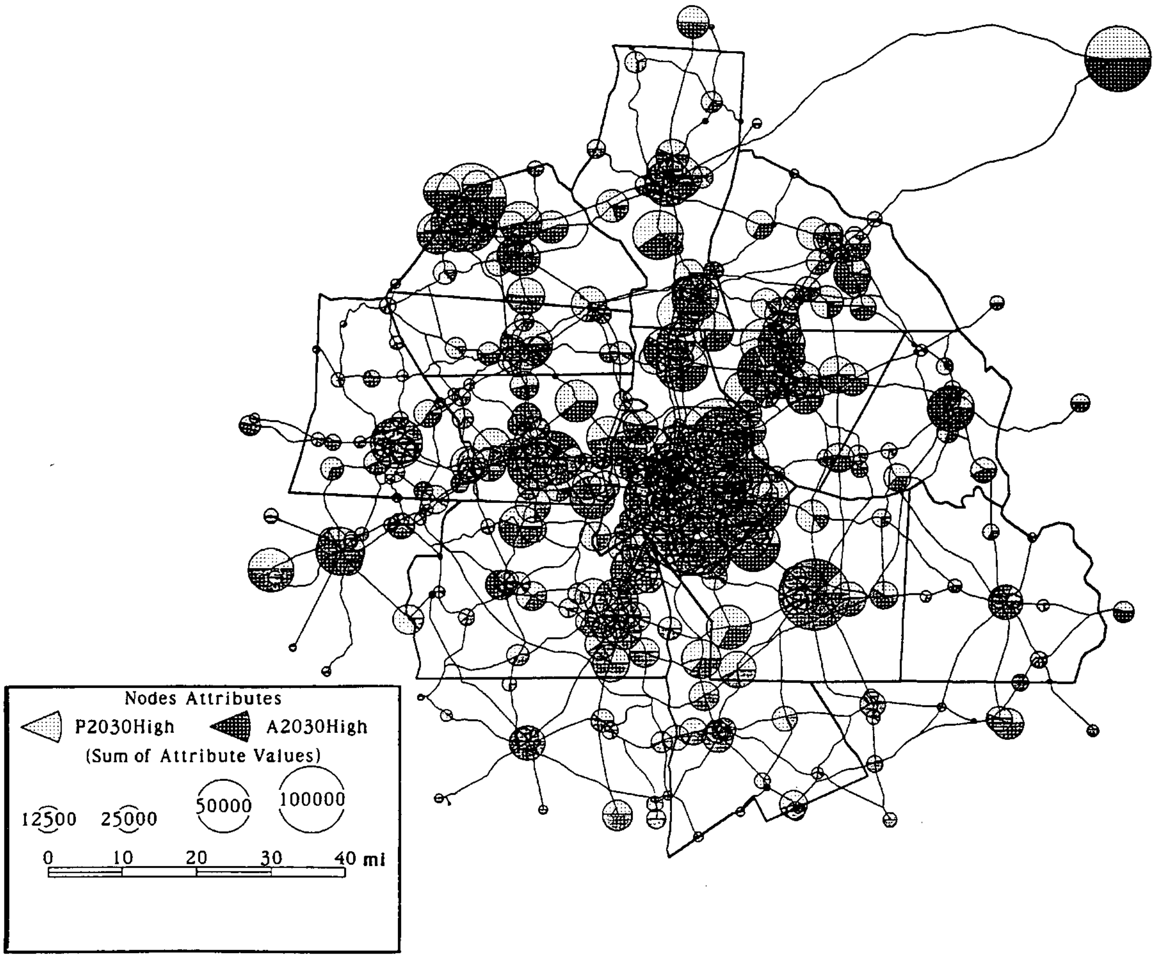

FIGURE 4 Productions and attractions for 2030 high parkway influence scenario.

BENEFITS OF GIS-T APPLICATIONS

On the positive side, GIS-Ts with transportation models provide a number of useful analysis features. Among these are visual power, multiple evaluations, coordinated regional view, speed, power of diffused technology, and efficient data storage.

Visual Power

The ability of GIS to display results as a "picture" is extremely useful. Planners and analysts can quickly review the findings of a particular proposal and understand their implications, not only on traffic but on background demographics and land-use parameters. Basically, whatever layers are in the GIS can be used as displays, both visual analytical, and summarized against the traffic findings. For instance, it would be straightforward to "buffer" various roads to determine land uses likely affected by a proposal. Regional energy and air pollution models could also be attached to the GIS, which would "take down" the traffic forecasts and convert them into energy and air pollution constraints. All of these analytical capabilities are more easily achieved with a joint GIS transportation package than with either GIS or transportation packages separately.

Multiple Evaluations

Once a network is coded and the system is operational, a wide variety of alternative evaluations can be studied in great detail. The capability to undertake this effort is important for refining the initial efforts made in the study. Basically, these features increase the ability of the agency to respond to the needs of its clients. Joint display of findings from several evaluation tests is a useful feature in identifying how alternatives affect the region.

Coordinated Regional View

It is clear that without the use of a regional model, policy proposals such as the Carolina's Parkway could not easily be studied. Regional models require coordination and cooperation to build. This model was not developed by any one of the MPOs in the regions or either of the two state highway

FIGURE 5 Traffic forecast for 2030 high parkway influence scenario.

departments. Instead, an independent organization working with UNCC, which had no responsibility for transportation planning or investment, developed the model. Of course, regional models can be built in non–GIS-T environments and similar problems will be encountered. The GIS-T application, however, can be less threatening because it does not use any agency's preferred tool.

Speed

The GIS-T procedure was able to evaluate alternatives very rapidly: within a day or two, new alternatives could be developed and analyzed against the existing system. The ability to generate alternatives rapidly and to evaluate them quickly requires trade-offs with scale and context. In this case, the very long-range nature of the modeling, in conjunction with a high-level sketch planning scale, makes the GIS-T procedure appropriate for "first cut" analysis of these proposals.

Power of Diffused Technology

If the diffusion of microcomputer transportation planning packages has increased the power of regional planning agencies and the diffusion of GIS capability has increased the power of organizational data bases then clearly the union of these two powerful features should produce an even more relevant tool.

Efficient Data Storage

Although many transportation models can and do store extensive data, GIS-T systems are particularly adept at this capability. GISs are designed to integrate data functions together, particularly data capture, storage, and display. They can also directly link these features to other more complex functions, including spatial queries, modeling, extraction, and expert systems. Direct updating from screens is also possible.

Data additions or parallel comparisons are also a useful feature. Often a project's data system will require that more data be added than originally planned for. Inclusion of new data items in traditional UTPS models is quite difficult because they typically require "this and only this" formats or fields to operate. If, for instance, data records on a new item such as a business opinion survey are to be displayed, most traditional UTPS packages would disallow that.

LIMITATIONS AND CONSTRAINTS OF GIS-T APPLICATIONS

On the other hand, this exercise found that a GIS structure can impose significant limitations and constraints on the modeling process. Among these are mismatches between GIS and transportation models, overly simple model extensions, lack of accuracy, and incompatability of results.

Mismatches Between GIS and Transportation Models

Blends of models sometimes produce a "camel," which is less functional than either of the original models. In some ways this is the case for GIS-T. Present GIS-Ts are not urban transportation planning models and do not have all the features that transportation planners expect. In particular, they are missing the following common features:

- Friction factors,
- Multiple trip purposes,
- Trip frequency distribution calibration,
- Multipurpose gravity model,
- Mode choice functions,
- Trip generation function,
- Automobile ownership forecasting, and
- Speed feedbacks.

On the other hand, UTPS models typically do not have all the features of GISs. TransCAD, perhaps the most sophisticated GIS-T, lacks some of the geographical display and visual power of, say, ARC/INFO.

Overly Simple

Present GIS-Ts have essentially simple UTPS model extensions, which are generally too weak for many common modeling problems. For instance, TransCAD's trip-purpose limitations (one purpose only) effectively limits it to specialized, sketch-planning or one-purpose problems.

Lack of Accuracy

It proved difficult, even with extensive screenline and travel penalty adjustment, to calibrate the base model on a corridor or link-type basis. This is because, the authors suspect, that the one-trip-purpose requirement produces an average trip distribution that does not well replicate the multiple circumstances of large complex regions. For sketch planning purposes, the calibration was sufficient, but it would be insufficient for more sophisticated urban modeling. In forecasting, residual errors that would not be resolved in calibration were adjusted for through the pivot point procedure. This method, although acceptable also for sketch planning, is clearly less than ideal.

Incompatibility of Results

A continuing problem that GIS-T users will face, if they propose to use GIS-T for modeling traffic, is a reluctance on the part of others to accept the results as valid. A recent survey of UTPS software technology (*18*) showed that the market of MPO users is divided as follows:

Package	*Percentage of Market*
TRANPLAN	30
MINUTP	25
QRS, I and II	19
TMODEL, I and II	8
MICROTRIPS	5
FSUMTS (Fla)	5
TransCAD	1
EMME II	1
Others	6

Of these, only TransCAD is generally recognized as a GIS-T, although other systems have some GIS-like features, particularly data display. It would therefore be understandable that an agency familiar with the UTPS package would be reluctant to switch to a GIS-T or accept GIS-T results.

In this study, the final report (*12*) calls for remodeling the parkway sections in Phase 2 using a more traditional UTPS microcomputer model package. Given the model limitations, this is understandable. For closer-in analysis (fewer than 20 years) more confidence in the model and its forecasts is needed.

RECOMMENDATIONS

What should be done to facilitate GIS-T use and bring models together? The authors suggest the following:

- Vendors can develop smooth interfaces between GIS and transportation model packages. It should not be necessary to manually manipulate or repackage data to "see" results. A recent survey of systems (*19*) showed that of ten systems, four had GIS interfaces and three had GIS interfaces under development.
- More sophisticated GIS-T can be developed containing full-function UTPS models and GIS features together.
- Federal agencies and trade organizations can set standards and guidelines for model use and operations, thereby encouraging the development of integrated tools.
- Applications developers can focus on targeted applications that provide opportunities for blended methods. Several examples that could be explored are combination GIS–Air-Quality–UTPS models, models of intermodal transfer and operations, hazardous waste routing, route-corridor impact locations models, site-level impact models, and interstate-intercity model planning.

In summary, the opportunities for GIS-T packages in super-region contexts are extensive and essentially unexplored. Transportation planners and analysts in super-regional environments are encouraged to look carefully at geographical information systems, particularly those blended with transportation models, as a means to facilitate and encourage the coordination and cooperation that they have for so long asserted.

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