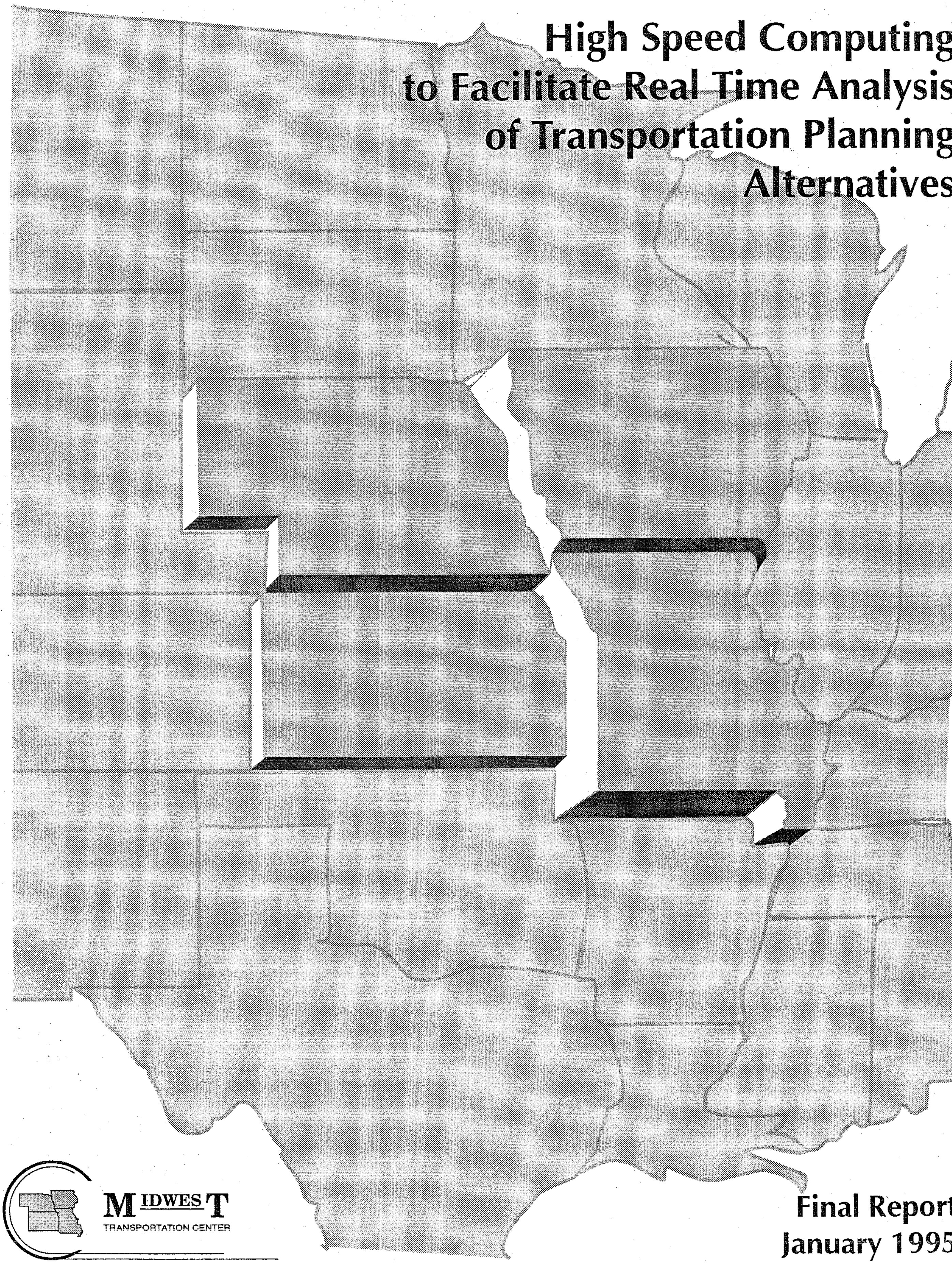
High Speed Computing to Facilitate Real Time Analysis of Transportation Planning Alternatives



MIDWEST
TRANSPORTATION CENTER

Final Report
January 1995

Midwest Transportation Center

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ABSTRACT

The first large-scale transportation studies were performed in the 1950s. This occurrence coincided with the development of the digital computer, which by that time had progressed such that large amounts of data could be manipulated and analyzed. Computing has progressed rapidly since, so that today more detailed and computationally demanding models of large metropolitan areas can be executed on desktop computers in a few hours or less.

Transportation problems are spatial and temporal in nature. They are also data-intensive. Geographic information systems (GIS), with their database and geocoding capabilities, are powerful tools for transportation data manipulation and analysis. Presently, transportation planning regional modeling efforts are costly and labor intensive - many projects requiring multi-year programs. Often, the final product is one or several "snapshots" of future travel patterns in an area. Alternatives analyses (spatial) are limited due to labor and computing constraints. For similar reasons, temporal variations in travel demand patterns are rarely accounted for.

This project built upon previous experiences with supercomputing and GIS. It investigated procedures for integrating supercomputer and GIS capabilities in transportation modeling. The researchers working on this project had previously successfully linked TRANPLAN and a GIS program (ARC/INFO) on computer workstations. This batch mode linkage was limited, however, to exploiting the data management and output capabilities of GIS. Further, the time required for a single run of the travel demand model for a medium to large region (about one hour on a fast workstation) prohibited the interactive viewing of outputs resulting from changes in assumptions and data.

Supercomputing presented several opportunities for transportation planning - opportunities which went well beyond being able to run models at high rates of speed. The goal of this project was to demonstrate the usefulness of high speed computing to transportation planning. The goal was met by developing an interactive system whereby GIS can be used to change demand model inputs, call for a run of the travel demand model on a mainframe computer, and display the results. The user interface is a multi-layer thematic map graphic which improves the user's ability not only to modify data and assumptions, but to recognize the implications of changes through overlay of input and output networks.

This project initially included compiling source FORTRAN code for selected transportation planning model modules. The code was provided by one of the Nation's largest developers of transportation planning software, the Urban Analysis Group of Danville, California. The program, TRANPLAN, is a regional travel demand model capable of generating, distributing, and assigning traffic to a highway or transit network. TRANPLAN is the model chosen by the Iowa DOT (among others) and its respective Metropolitan Planning Organizations. Using the high-speed processing capabilities of a mainframe or PC front-end to a Cray YMP-2 supercomputer or DEC Alpha workstation was intended to produce an executable code with speed capable of supporting interactive analysis. Although attempts to compile the software on the Cray and DEC Alpha workstation were unsuccessful, the system as developed demonstrates the usefulness of using high speed computers and GIS for transportation planning.

During an interactive session, an analyst may perform several alternatives analyses, investigating the outcomes (congestion, delay) resulting from various transportation planning

decisions (adding new infrastructure, deploying travel demand management strategies, modifying land-use assumptions).

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. PROJECT OVERVIEW

Project Description

Project Missions

The missions of this project were threefold. The first mission entailed assessing the need and viability of high-speed computing with GIS for transportation planning, research, and other functions. The second mission required establishing procedures for integrating high-speed computer and GIS capabilities in transportation modeling. The final mission encompassed the identification, planning, design and implementation of GIS-based tools to facilitate alternative selections and policy analysis.

Project Scope

The scope of this project included development of a prototype system of linkages between a travel demand model (Tranplan) and a geographic information system (Intergraph's MGE/MGA series) first in a PC environment and ultimately running on high-speed computers. The data chosen for development of the system were first a network of manageable size (the sample network provided by the UAG) and later extended to include larger metropolitan areas such as Des Moines, Iowa.

Project Objective and Outcome

The objective of this project was to demonstrate the capabilities of travel demand models in a high-speed, GIS-based environment. Using tools developed in this project, during a one to two hour interactive session, an analyst may perform several alternatives analyses, investigating the outcomes (congestion, delay) resulting from various transportation planning decisions (adding new infrastructure, deploying travel demand management strategies, modifying land-use assumptions).

The primary product from this project is a prototype system which can be used to identify and assess transportation impacts in medium to large urban and suburban regions/areas. Analytical capabilities include spatial overlay of origin-destination information on socioeconomic and demographic data. The tools developed in this project enhance the ability to provide for equitable and efficient allocation of resources (GIS can effectively compute and display derived data on cost per lane mile or jurisdiction, spatial distribution of benefits, etc.)

Approach and Methodology

The approach taken in this project included two parallel efforts, one involving compilation and testing of Tranplan on high-speed computers and the other involving development of GIS to Tranplan linkages. The tasks which facilitated this approach are outlined below:

Task 1: Develop/test workstation-GIS to PC-Tranplan linkages. Two workstation-GIS to PC-Tranplan linkages were within the project scope. The first linkage served as a means to create a GIS model network from Tranplan data files. The second linkage enabled a two-way dat exchange between the workstation-GIS and PC-Tranplan.

Task 2: Partial Compilation of Tranplan on the Cray and DEC Alpha workstation to determine the time required to run individual Tranplan modules on these platforms. Knowing benchmark execution times for several Tranplan modules, the execution times of other modules may be estimated. Due to difficulties and time limitations, Tranplan could not be fully compiled on either the Cray or the DEC Alpha workstation.

Task 3: Demonstrate the system. System demonstration entailed creating a GIS model network from Tranplan data sets and performing alternatives analyses utilizing GIS, the two-way data exchange linkage, and Tranplan.

Task 4: Prepare final report.

Results

The primary deliverable resulting from this project is a working system linking a travel demand model (Tranplan) and a geographic information system (MGE/MGA). Although attempts to compile the software on the Cray and DEC Alpha workstation were unsuccessful, the system as developed demonstrates the usefulness of using high speed computers and GIS for transportation planning. Given more time and more importantly, computer programming and systems support, a supercomputer could be utilized to improve the performance of the system. Moreover, as additional transportation and air quality models are integrated with GIS, there will be an increased need for supercomputing application. These and other issues and outcomes are discussed more fully in the chapters which are described below.

Þ Chapter 2 motivates the need for high-speed transportation planning/GIS systems by analyzing four regional travel growth scenarios. A fifth scenario based on region-specific expert information using GIS is suggested.

Þ Chapter 3 describes the development of a GIS-travel demand model interface (Intergraph's MGE/MGA and Urban Analysis Group's Tranplan). Outlined are the processes of: utilizing Tranplan data sets to create a base transportation network in the GIS environment, integrating various graphical and non-graphical data sets, and developing alternatives and sensitivity analysis capabilities within the GIS.

Þ Chapter 4 describes three applications of the system on an Intergraph/PC platform: 1) using GIS to develop or modify UTMS models, 2) building a GIS from UTMS network data, and 3) a high-speed interactive loop for alternatives and policy analysis.

Þ Chapter 5 concludes the main body of the report. In this chapter the investigators conclude that the Transportation Planning GIS (TPGIS) provides an analyst with the ability to modify data and assumptions and to recognize the implications of changes, and, although the system as developed uses a combination of advanced hardware and sophisticated software, technology is becoming available to many planning organizations to allow similar capabilities (desktop mapping and high-speed yet affordable personal computers). Development of an accessible version of the TPGIS utilizing standard hardware and software available to State Departments of Transportations, Metropolitan Planning Organizations (MPOs), and Regional Planning Affiliations (RPAs) is recommended.

Þ Appendix A provides an overview of the hardware/software platform selection process and then describes the platforms selected.

CHAPTER 2. ANALYSIS OF TRENDS UNDERLYING THE URBAN AND REGIONAL IMPACTS OF TRAFFIC GROWTH

BACKGROUND: Historical Significance of VMT Policy

Historically, VMT has been used as a measure of the levels of: 1) vehicle use, 2) traffic, 3) traffic growth, and 4) travel demand. Actual and forecast levels of VMT have been included as factors important to sound transportation policy decisions. Owen and Dearing argued in 1951, for example, that a condition underlying the demand for the Pennsylvania Turnpike (the first modern U.S. toll road) and other similar highways was an increase in the number of vehicles and VMT (Rao 1992). More recently, three FHWA activities were identified as directly requiring highway vehicle travel forecasts. They include highway policy analysis, fiscal planning (allocation of funds and revenues), and highway program planning (Southworth 1986). Existing VMT levels and forecasts play roles in strategies related to 1) congestion alleviation, 2) investment decisions, 3) system capacity for civilian and defense needs, 4) evaluation of environmental impacts of alternative transportation investments, 5) identification of magnitude and effects of transportation impacts on the environment, 6) development of policies to mitigate adverse impacts, 7) evaluation of energy performance of alternative transportation modes, and 8) monitoring energy performance of the transportation sector (TRB 1992).

Motivation

Projected growth in vehicular traffic is a controversial issue for transportation planners. Forecasts are used to make strategic decisions including whether to build new highways, how best to allocate resources for maintenance, and how to design effective transit and freight transportation policies, among others. However, proposed capacity-increasing projects have been stopped in hopes that limiting supply would limit demand. Air pollution concerns may prohibit building new roads which cannot be shown to reduce demand for single-occupant vehicles. Some argue that building more infrastructure will only encourage more traffic.

Stimulated by the ongoing debate on the future of transportation directions and investments, this paper aims to provide some suggestions for travel forecasting. Another motivation is to examine simplified methods of traffic forecasting. Overall, we suggest a simpler way to think about and forecast VMT. A simple model for VMT forecasting for highway planning should use available data, be based on theory, be transferable (locally, regionally), be based on causal variables which are predictable, and be easy to apply (Southworth 1986).

Scope

This paper presents a simple, self-limiting model for VMT forecasting which assumes that travel growth is similar to other transportation system growth patterns. Following development of the model, national and state data are presented to show the usefulness of the model. At regional (metropolitan) scales, the model's components are less predictable, prompting an analysis into the effects of increased travel on the negative impacts of transportation. While the regional effects of increased travel on delay and emissions vary with trip length and spatial distribution characteristics, current policies treat all travel (VMT) growth the same (particularly in highly polluted areas). In this paper, models are developed for several spatial travel growth scenarios. Four scenarios (uniform growth, random growth, growth in congested segments of networks, and growth in uncongested portions of networks) are tested using origin-destination (O-D) inputs to a UTPS-based microcomputer model modified by several FORTRAN programs. A proposed fifth scenario, growth patterns predicted using local knowledge, would involve the use of geographic information systems as a possible tool for scenario management, alternatives analysis, and sensitivity analysis. Results of the four scenario analyses indicate widely varying manifestations of increased travel on delay, prompting a re-examination of policies which do not allow for the consideration of planning strategies or capitalize on underlying trends. Although trucks are responsible for one quarter of all VMT on the nation's roads, this paper focuses on passenger, and in particular, automobile transportation (BTS, 1993).

Review of Relevant Policies

Policies initiated by national transportation legislation, such as the Clean Air Amendments of 1990 (CAAA) and the Intermodal Surface Transportation Act of 1991 (ISTEA), are intended to foster innovative approaches to solving transportation problems, but these policies often also serve to further strain already challenged regions. The policies set forth in CAAA and ISTEA were apparently developed assuming a continuation of recent, phenomenal VMT growth. CAAA and ISTEA policies essentially mandate awareness and control of VMT growth and VMT growth impacts. In some areas, such policies may actually be unneeded and be counter-productive by restricting mobility and economic and social development.

The transportation-related provisions of CAAA have renewed the emphasis on controlling the growth of VMT in Federal Air Quality Standards "non-attainment" areas (Shrouds 1992). These provisions are realized in programs which mandate: 1) VMT reductions, 2) VMT tracking, 3) adoption of transportation control measures (TCMs) to reduce VMT growth, and 4) requirements for employers of 100 or more to reduce work-related trips and employee VMT (Shrouds 1992). The CAAA permits the EPA to apply sanctions to any portion of a state, or an entire state, that it deems reasonable and appropriate. Federal funding may be withheld from an area failing a state implementation program (SIP) requirement. The USDOT must also follow strict regulations with respect to the projects it may approve and the grants it may award after highway sanctions are imposed. Only certain safety projects and projects not encouraging single occupancy vehicles may be considered (Shrouds 1992).

ISTEA has carried forward the CAAA's theme of VMT control and reduction. Travel demand reduction is addressed in the context of the congestion management system (CMS) and statewide planning requirements. Specifically, reduction in traffic congestion is required. Prevention of traffic congestion in areas where it presently does not exist and reduction of motor vehicle travel, particularly single-occupant motor vehicle-travel, are also expected (ISTEA 1991).

Existing policies treat all travel growth as a negative. Little distinction is made between different distributions of travel growth. Both ISTEA and CAAA are fairly explicit in their descriptions of the required results of their policies and the actions that may be taken to achieve these end-results. Realistically, capacity expansion in non-attainment areas will stop unless we have a better understanding of VMT growth.

Review of Existing Models

Many models have been developed to forecast the aggregate growth of VMT. Southworth has provided a concise review of most of the models now in use (Southworth 1986). Many of these models exhibit high correlation coefficients when fit to short term (10 to 20 year) trends. However, most are trend projections lacking theoretical foundation. Other, more theoretical models are based on causal variables which are more difficult to predict than VMT itself. Existing models use independent variables such as: fleet size, operating cost, fuel shortages, fuel price, consumer wages, vehicle prices, consumer prices, number of households, fuel economy, and others including rural population, miles of transit, and unemployment rate. Southworth has suggested that the most immediate methodological need may be to "find a way to introduce a more theoretically appealing structure into the causal modeling of VMT" (Southworth 1986).

The introduction of variables that have economic, demographic, and supply interpretations is certainly a desirable alternative to projecting past trends based on the underlying assumption that things will go along as they have gone. The view we will discuss does not reject the relevance of either economic and social considerations or projecting past trends. Rather, it says that past trends overlook the maturing of the automobile-highway system--the adoption and use of the automobile and adjustments of related organizations and institutions have run their courses.

National Trends

Historical estimates of VMT are available based on sample vehicle counts and surveys, motor fuel sales and fleet average fuel economy (Southworth 1986). Projecting trends, Fig. 1 shows that national VMT appears to be growing with no signs of slowdown (Census Bureau, 1975; Census Bureau, 1971-93). As many urban facilities are operating at capacity, there seems to be cause for concern. Taking a longer look, on the time scale of Fig. 2, VMT growth is exponential--even more alarming.

A Simple, Self-Limiting Process

Conventional traffic forecasting is a complicated process. Traffic is generated by trip making, and there are many classes of trips: local and through, work related (commuting, trip) and non-work related (personal business, shopping, recreation, school/church, etc.), rural and urban, and passenger (personal vehicle, public transit) and commercial (freight, service). Conventional analysis forecasts traffic generated by each of these trip types--we take a simpler approach.

Transportation systems are birthed, deployed, and, unless shoved aside by competitive systems, muddle along in maturity. Their life cycles are well represented by S-curves, and Grubler (1990) has plotted curves for many infrastructure systems and discussed their evolution and technological change. Similar but less sweeping efforts have been made by others (e. g. Garrison 1990; Nakicenovic 1988). What can be said about the life cycle of VMT (or more appropriately the life cycle of the automobile/truck/highway system of which VMT is one

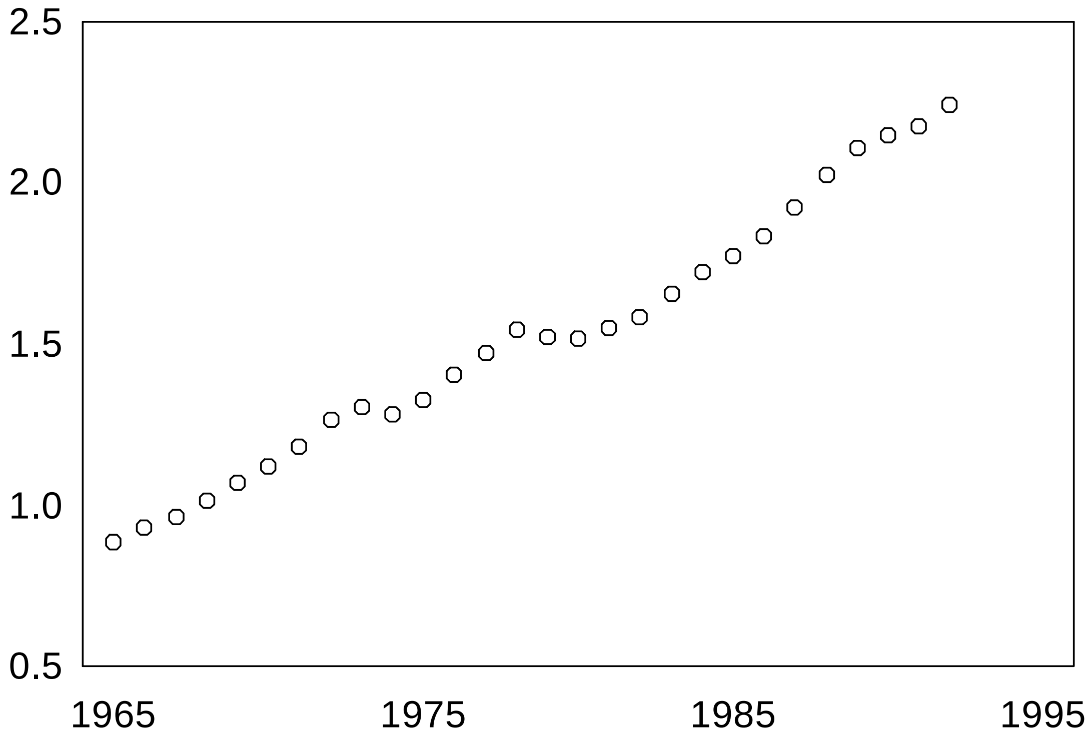

Fig. 2.1 USA VMT 1965-1990 (trillions)

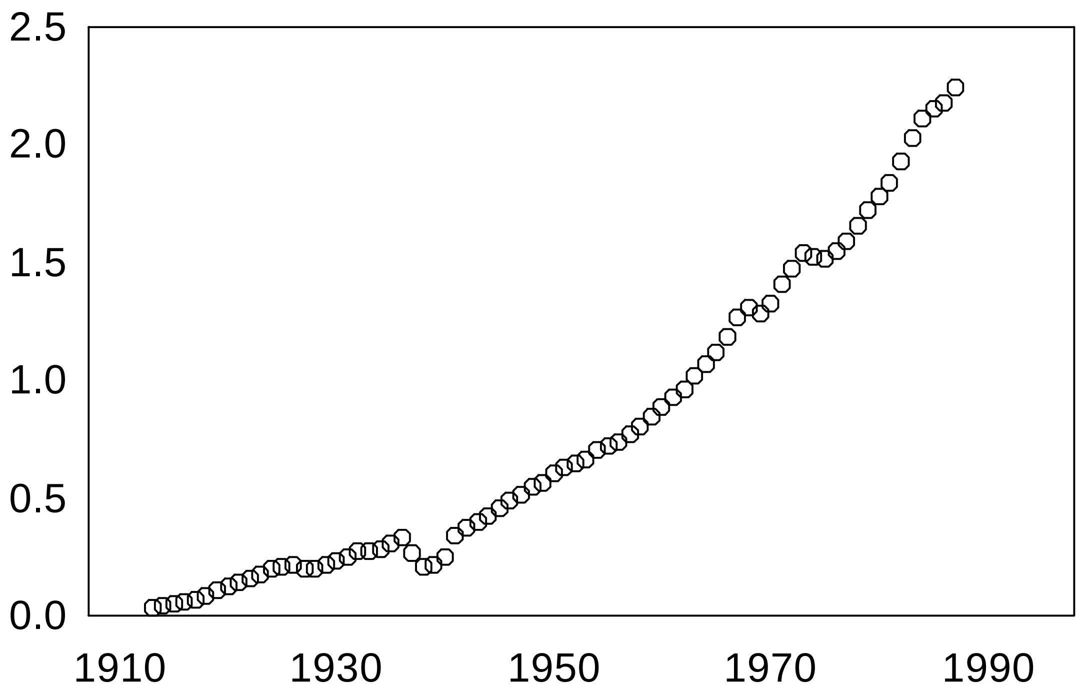

Fig. 2.2 USA VMT 1910-1990 (trillions)

measure of system deployment)? While VMT does not at first appear to follow an S-shaped growth process, we will examine its components for trends.

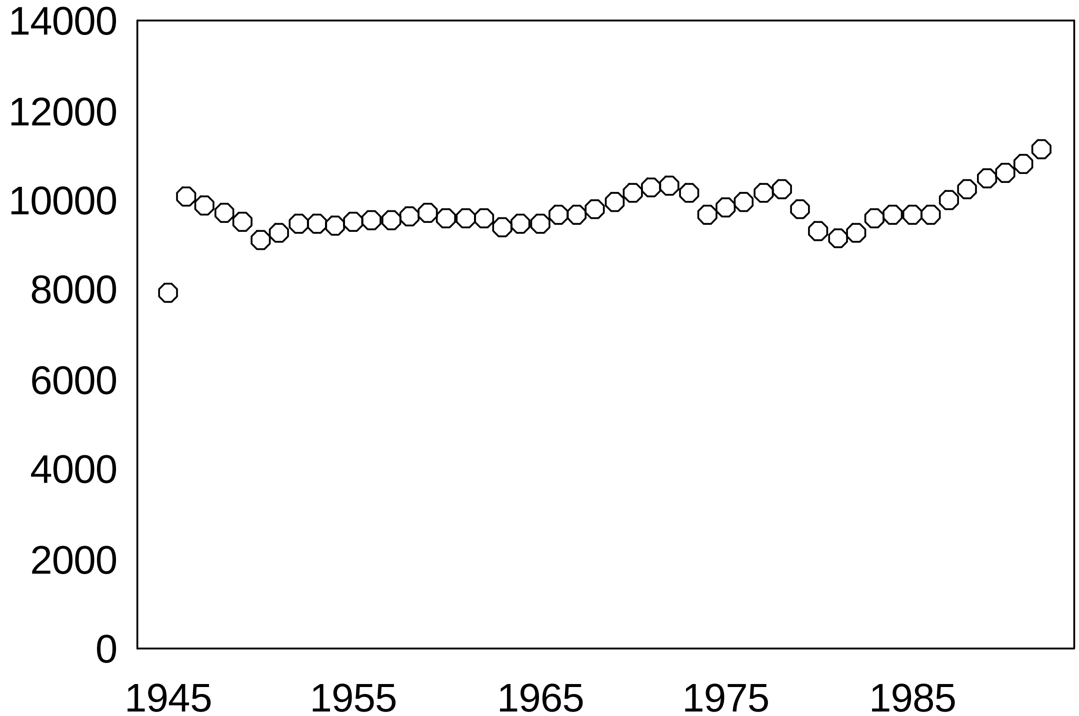

Fig. 2.3 Miles per Automobile per Year in the USA

We may think of VMT as the product of several components: the number of vehicles per capita, population, and the number of miles driven per vehicle. (An equivalent result could be obtained by multiplying the number of drivers and the average miles per driver.) Historically, the miles driven per vehicle has been fairly stable, around 11,000 miles per year (see Fig. 3). Therefore, most of the increase in VMT observed over the past several decades must be attributed to more vehicles, not more miles per vehicle. The number of vehicles depends on two factors: 1) the driving-age population, and 2) market penetration of vehicles, essentially a mature process, (see Fig. 4). Fig. 5 shows the third component of VMT growth, driving age population. Following historical trends, increases in automobile VMT over the next few decades must come from increases in population and from the penetration of the automobile into its last remaining markets, older persons and the economically disadvantaged. (Non-household fleets are not accounted for in this analysis.)

Other research in this area has produced similar findings. Lave attributes the past, rapid VMT growth to increasing numbers of vehicles - increasing much faster than population. He foresees actual VMT growth rates leveling off to a rate one-third as large as that recently experienced. Lave identifies several historic trends to support his theory. These trends are as follows: 1) the growth rates of vehicles and population are now nearing equality; 2) the growth rate of vehicles per driving-age population has decreased; 3) the ratio of vehicles per population has begun to level off; 4) VMT growth has closely tracked with growth in the number of registered vehicles; 5) average VMT has remained fairly constant from 1969 to 1983 (Lave 1990); and 6) the United States is nearly saturated with vehicles - .95 vehicles per person of

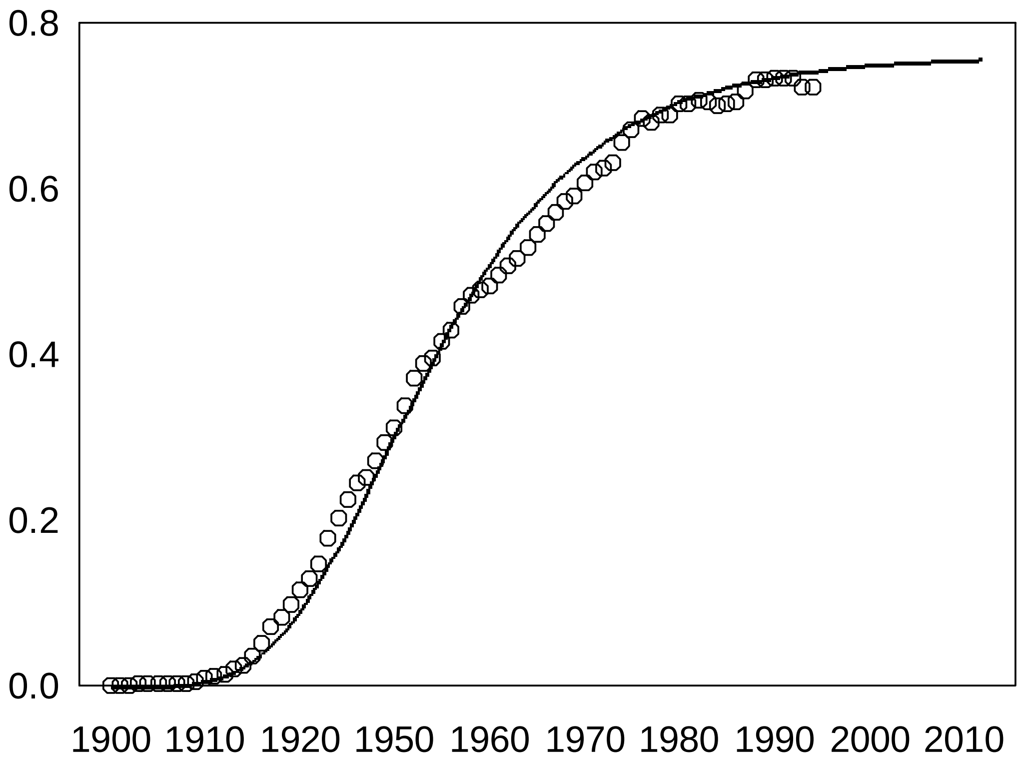

Fig. 2.4 USA Auto Registrations per Capita

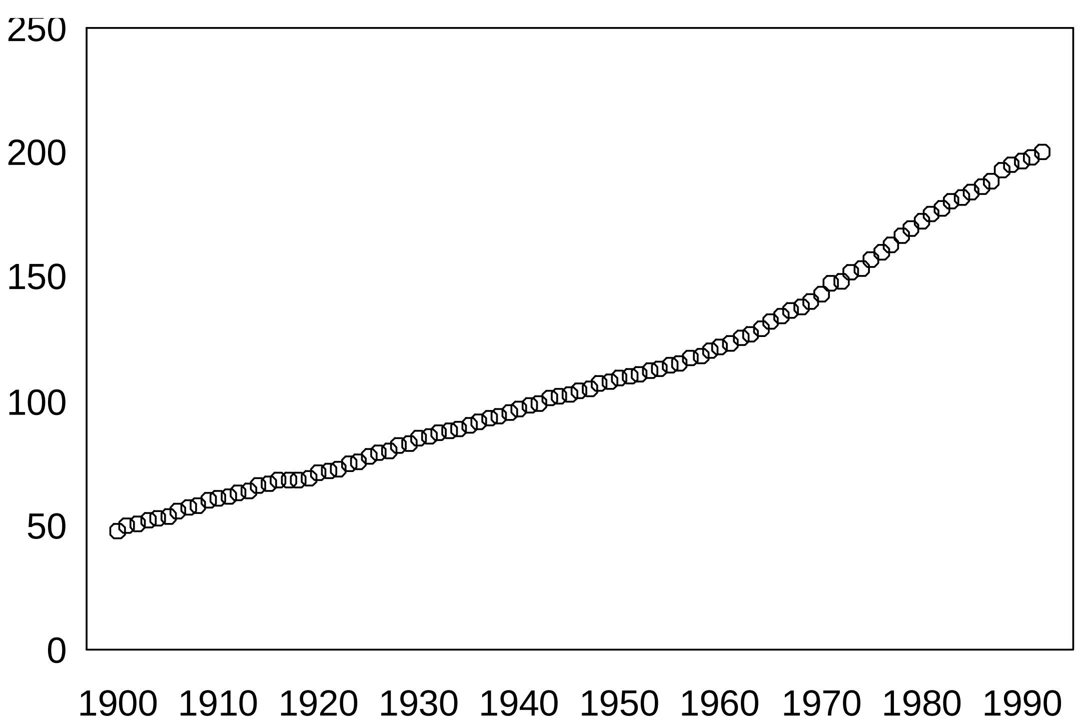

Fig. 2.5 USA Driving Age Population (millions)

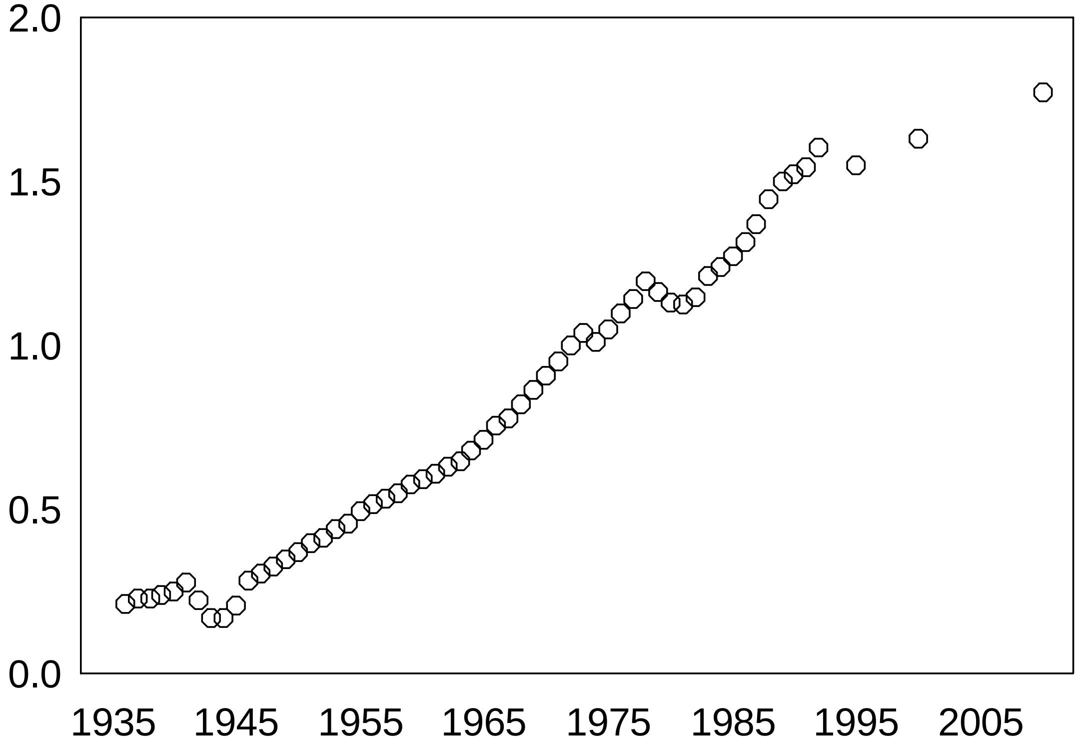

Fig. 2.6 USA Forecast VMT (trillions)

driving age in 1989. Lave, however, does not expect additional vehicle growth to result from zero-vehicle households purchasing vehicles (Lave 1992).

The situation can be put this way. "Automobilization" in the U.S. began early in this century. Nowadays, it is approaching market saturation. It is in that sense that the process of VMT growth is self-limiting.

Extrapolation of Component Trends

The miles driven per year for automobiles has been oscillating around what appears to be a set point just under 11,000 miles per year. There is not much reason to expect this trend to change. Miles per year is the product of miles per trip and trips per year. National Personal Transportation Survey's *Summary of Travel Trends* reports an increase of only 0.1 miles in average trip length between 1969 and 1990. Trips per year per auto have actually declined during the same period. (While not material to the current discussion, it is interesting to note that 0-2 year old vehicles are driven nearly 16,000 miles per year and older vehicles less. (FHWA 1992)

Commute travel times have changed very little over the past several decades. In the 1930s, people traveled 20 minutes to get to work. Today, they travel approximately 20 minutes to get to work (22.4 minutes in 1990), even in congested cities like Houston - approximately 26 minutes in 1990, Los Angeles - approximately 26 minutes in 1990, and New York -

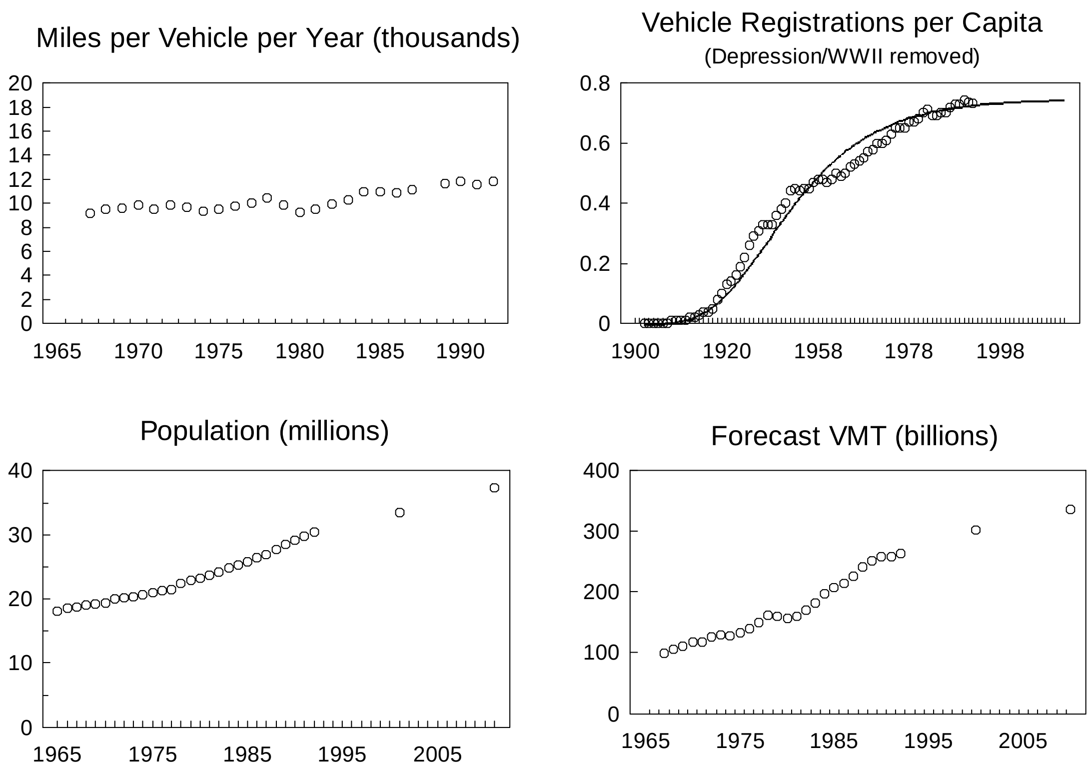

Fig. 2.7 California VMT

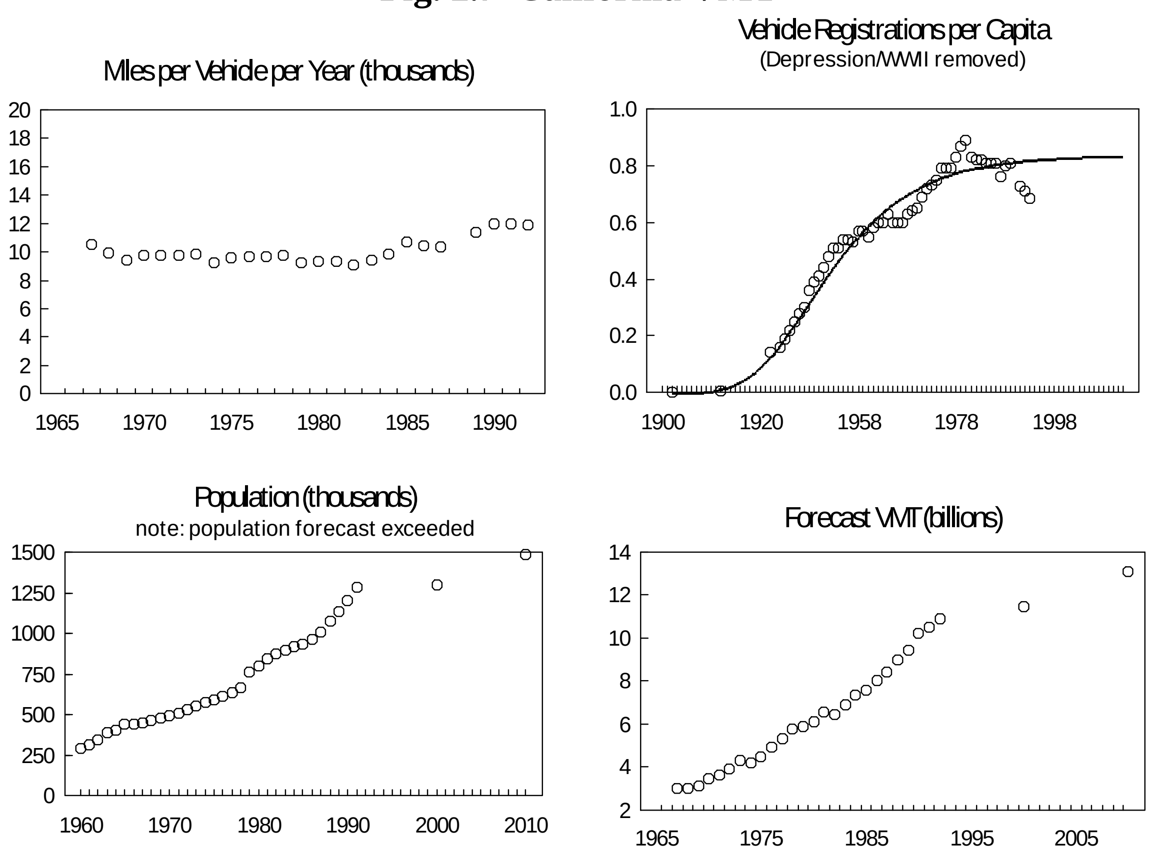

Fig. 2.8 Nevada VMT

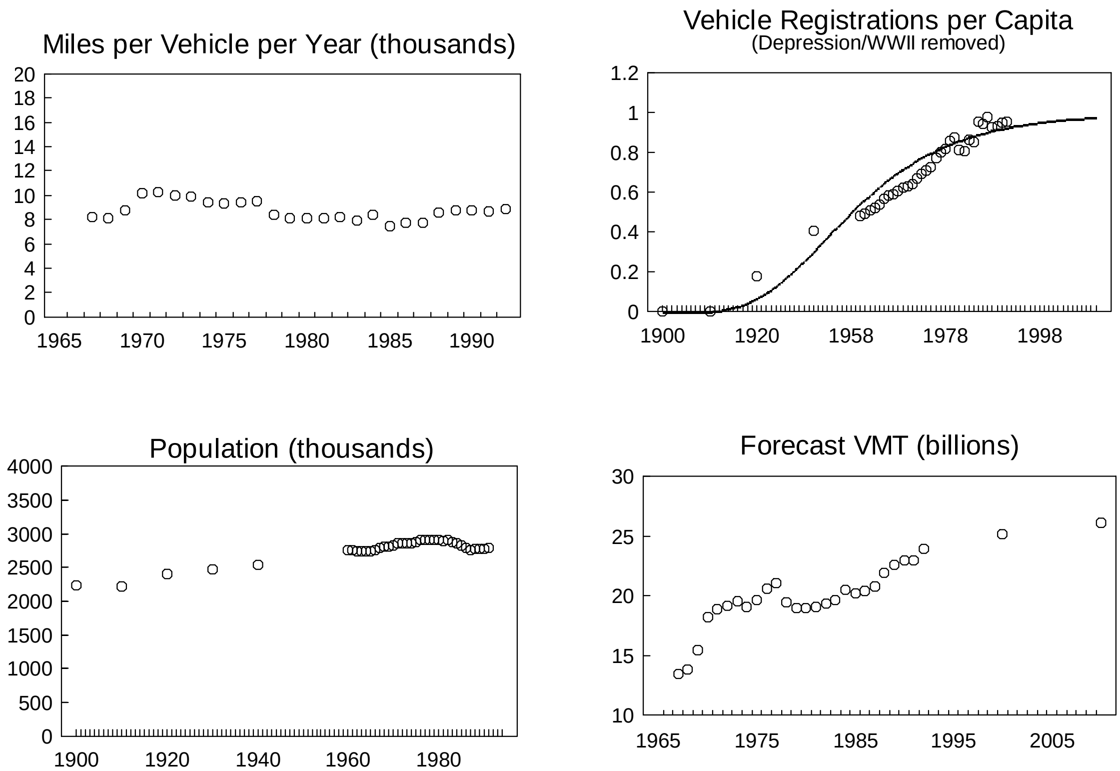

Fig. 2.9 Iowa VMT

approximately 29 minutes in 1990 (USDOT 1993). Non-work trip lengths are decreasing as more businesses and services are locating in or near residential areas.

The growth of vehicles per driving age population is representative of a class of simple dynamic processes. We fit the data for number of vehicles per capita to one such dynamic model, a three parameter Gompertz curve, in order to make some estimates of the rate and saturation of automobile market penetration (see Fig. 4). Using Census Bureau estimates of population growth in the U.S. and multiplying the three component extrapolations produces our estimate for national automobile VMT (see Fig. 6).

State-level Trends

Data for population, number of vehicles, and VMT for the Nation as a whole and for all 50 states are available for analysis. An objective was to test the simple model for states of varying size and characteristics. Three states were chosen to demonstrate the model: California, Nevada, and Iowa. Historical VMT data were available only for total vehicles. Nonetheless, these data adequately illustrate the usefulness of the model. We extrapolated VMT per vehicle, vehicles per driving population, and population. (Inclusion of commercial vehicles in statewide data does create a problem, for commercial vehicles do not follow the same pattern of growth.

One potential option may be to design and obtain data for an alternative simple model, say, one based on the number of drivers licenses issued.)

Results of the specific state analyses are provided in Figs. 7-9 (FHWA, 1967-93, FHWA, 1987). Trends were extrapolated as they were for the national analysis.

Regional Applicability

The proposed method of predicting VMT should be most effective applied on a national level as demographers have provided many predictions of the chief causal variable, population growth and composition. The U.S. is expected to grow much more slowly in the next few decades than in the past several. However, the model is likely to be less effective on a regional basis, where population shifts are less predictable. In addition to inter-regional migration, shifts have included population movements from rural areas to the cities and from cities to the suburbs. While regional traffic may be a function of population shifts, regional congestion is a much more complex end-result of regional traffic, travel patterns, and capacity and design of the highway infrastructure. Specifically, six forces contribute to regional traffic congestion: 1) suburban development, 2) economic development, 3) labor force, 4) automobile use, 5) truck traffic, and 6) highway infrastructure (USGAO 1989).

Relation between Regional Travel Growth and Delay

We know that increased VMT yield increased congestion, and such is rightly regarded as undesirable. We also know that increasing VMT is inevitable in growing areas as population increases. More regional trips, in turn, precipitate higher regional VMT. However, it is the <u>effects</u> of increases in trip making on congestion and delay, air pollution, and mobility that bear close examination. These effects depend not only on the overall magnitude of trips, but also on their spatial distribution and resulting congestion.

Regionally, a mathematical model is needed for travel estimation. The most appropriate and effective model may be an area's existing calibrated network-based UTPS travel model (Fleet 1992). Potential uses of a UTPS model include: 1) calculation of growth factors using base and forecast year data (Fleet 1992), 2) simulation of travel growth, and 3) analysis of the effects of travel growth. A calibrated network-based (Tranplan) model for Des Moines, Iowa, was used to simulate various scenarios of travel growth and test the sensitivity of delay to this growth.

Travel Growth Scenarios

As regional travel grows, new trips are distributed throughout the transportation system. Trips can be distributed throughout the system in many different patterns. To test the sensitivity of negative impacts of transportation to increases in travel, four potential patterns/scenarios of travel growth and distribution are analyzed (and a fifth is proposed for future study): 1) uniform growth and distribution, 2) random growth and distribution, 3) growth and distribution in uncongested areas, 4) growth and distribution in congested areas, and 5) growth and distribution in areas based on knowledge and experience (proposed). In reality, growth may occur as a combination of each of these scenarios as described below:

Scenario 1, Uniform Growth and Distribution. Trips are distributed uniformly throughout a region as if regional population increases are also uniformly distributed.

Scenario 2, Random Growth and Distribution. This scenario assumes random location of population growth, and nonexistent or non-effective land use and growth control policies. Travel is added in a random fashion and is representative of a region where forecast traffic is difficult or impossible to predict.

Scenario 3, Growth and Distribution in Uncongested Areas. It is assumed that travel time dictates where people locate - therefore, most new regional growth will occur in areas experiencing little or no congestion. This might reflect a land use policy encouraging growth in little-developed areas and using available street capacity.

Scenario 4, Growth and Distribution in Congested Areas. This scenario assumes that location decisions are not influenced by travel time delay but are driven by the locations of existing activity centers. This scenario most closely models the effects of land use controls which prohibit location of trip-ends in non-populated areas.

Scenario 5 (proposed), Growth and Distribution in Selected Patterns and Areas (based on knowledge and experience). Modeling trip volume increases in selected patterns, such as neighborhood to neighborhood and neighborhood to central business district (CBD), would provide the most realistic representations of regional growth and its effect. Knowledge of existing and future land use plans, building permits, utility extensions, and other proposed infrastructure expansion provide analysts with insight into how a region may grow and where the growth may be distributed. Various patterns of growth and distribution could be analyzed in an attempt to evaluate potential policy decisions. This scenario would best represent current travel demand forecasting techniques, although current techniques do not allow for effective scenario management or the efficient testing of multiple alternatives.

Regional Growth Model

Modeling tools were developed to test each of the first four growth scenarios identified above. Several FORTRAN-based computer programs were written to enhance the capabilities of a commercially available UTPS-based modeling package (Tranplan). Integrated GIS-UTPS systems are currently being developed by the authors and others which could be used to test scenario 5.

The analysis of regional travel growth begins by examining existing, region-wide operating conditions. Given a model transportation network for Des Moines, Iowa, the free flow travel times between origin-destination (O-D) pairs are calculated. Free flow conditions exist when little traffic is present on the network. Zonal productions and attractions are then converted to trips, distributed throughout the region, and assigned to the model network, using an equilibrium loading technique. Total regional VMT and VHT (vehicle-hours traveled) are estimated, and existing travel times between O-D pairs are calculated. The difference between the free flow travel times and the existing travel times represents total region-wide delay. The ratio of total delay to VHT is the percentage of all regional travel experiencing delay, or congestion, under existing conditions. A similar value, the 'congestion index,' is a Tranplan output.

We now have base, reference values for O-D travel times, VMT, VHT, delay, and percent delay. We proceed by modeling each growth scenario individually. All scenarios are modeled using the same, constant system capacity and friction factors.   Equilibrium loading is also utilized for each scenario.

Scenario 1, Uniform Growth and Distribution. Uniform trip distribution is achieved by multiplying the entire O-D trip table by the desired percentage trip increase. This yields an O-D trip table which includes both existing and new trips. These trips are then loaded onto the model network. New values for O-D travel times and regional VHT and VMT are output. Total delay and percentage of all regional travel experiencing delay as a result of the uniform trip increase are calculated as before. (See Fig. 10 for an illustration of the first four growth scenarios.)

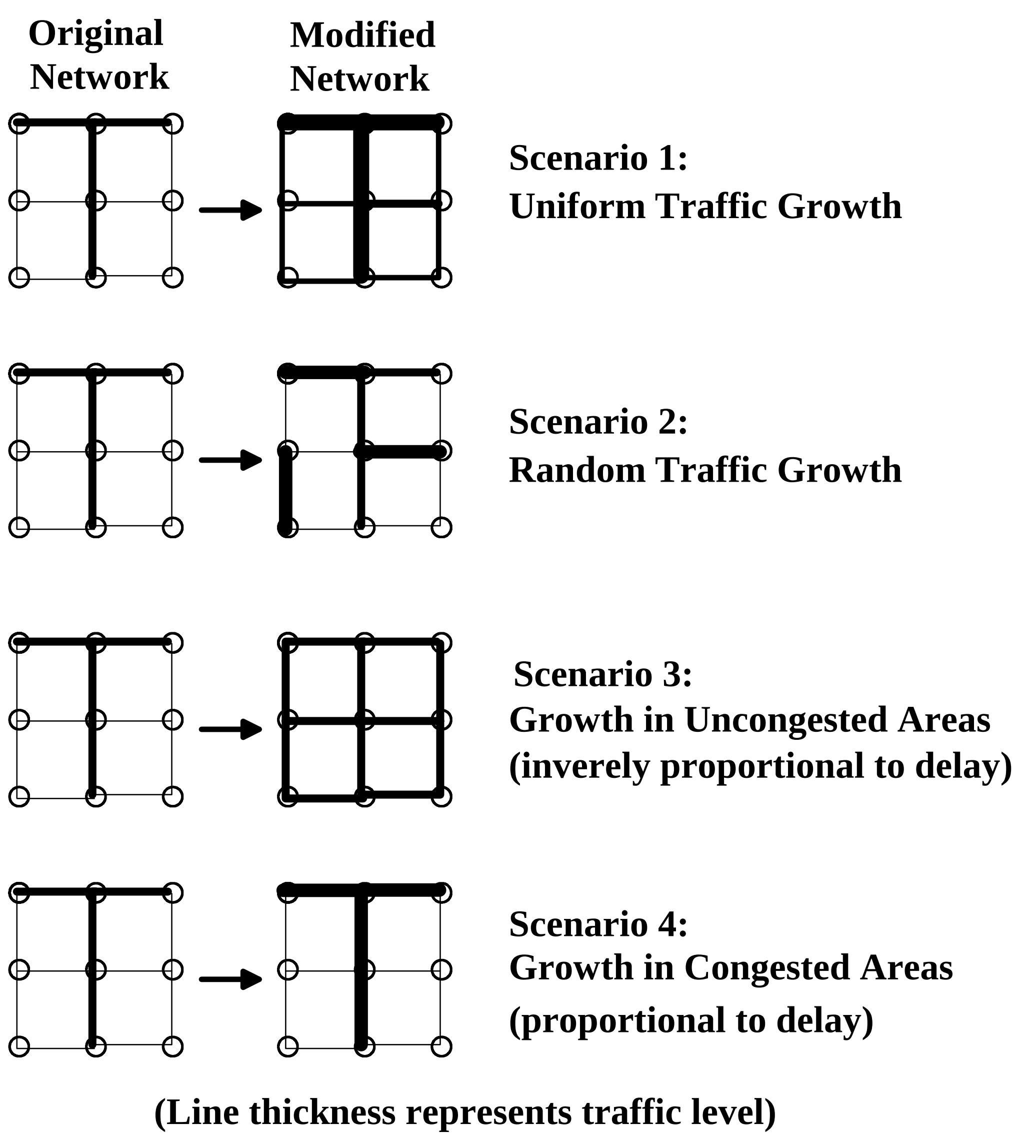

Fig. 2.10 VMT Growth Scenarios

Scenario 2, Random Growth and Distribution. Random trip distribution is achieved by randomly, and iteratively, adding trips to the O-D trip table until the desired percent increase is obtained. A new trip table including both existing and randomly added trips is created. These trips are then loaded onto the model network. New values for O-D travel times and regional VHT and VMT are output. Total delay and percentage of all regional travel experiencing delay as a result of the random trip increase are calculated as before.

Scenario 3, Growth and Distribution in Uncongested Areas. Trip increases are primarily a function of the ratio of base O-D travel times to free flow O-D travel times. Methodology:

- Trips are added to those O-D pairs possessing the lowest travel time ratios.
- A low travel time ratio suggests that little delay is experienced between the O-D pair, resulting from low trip activity or excess capacity. (Certain links on the O-D path may, however, be congested.)
- As the travel time ratio increases, fewer trips are added.
- No new trips are added to O-D pairs possessing a travel time ratio of two or greater.
- If the existing travel time is already twice the free flow travel time, we assume that no new trips will be made between the O-D pairs.
- New trips are iteratively added to the existing trip table until the desired aggregate increase is achieved.
- All base trips remain assigned to their original O-D pairs.
- A new trip table including both existing and newly added trips is created.
- These trips are then loaded onto the model network.
- New values for O-D travel times and regional VHT and VMT are output.
- Total delay and percentage of all regional travel experiencing delay as a result of the trip increase are calculated as before.

Scenario 4, Growth and Distribution in Congested Areas. Once again, trip increases are primarily a function of the ratio of base O-D travel times to free flow O-D travel times. Methodology:

- Trips are added to those O-D pairs possessing the highest travel time ratios.
- A high travel time ratio suggests that high delay is experienced between the O-D pair. We assume that these are the most active O-D pairs.
- As the travel time ratio decreases, fewer trips are added.
- New trips are iteratively added to the existing trip table until the specified aggregate increase is achieved.
- All base trips remain assigned to their original O-D pairs.
- A new trip table including both existing and newly added trips is created.
- These trips are then loaded onto the model network.
- New values for O-D travel times and regional VHT and VMT are output.
- Total delay and percentage of all regional travel experiencing delay as a result of the trip increase are calculated as before.

Scenario 5 (proposed), Growth and Distribution in Selected Patterns and Areas (Based on Knowledge and Experience). Linkages between standard UTPS-type models and geographic information system (GIS) are currently being developed and promise to be useful tools in modeling this type of growth. The tools being developed for this scenario will not likely modify O-D pairs, but rather they will adjust trip generation (zonal productions and attractions). Using the systems, an analyst will be able to graphically select and modify zonal productions and/or attractions to represent forecast growth. This, and other pertinent data, can then be output in travel model format. Zonal productions and attractions could then be converted to trips, distributed throughout the region, and assigned to the model network, using an equilibrium loading technique. New values for O-D travel times and regional VHT and VMT could be the output. Total delay and percentage of all regional travel experiencing delay as a result of the trip increase could then be calculated as before. Output data regarding the loaded network, such as travel times and volumes, could then be transferred back to the GIS. The GIS could be utilized to graphically display the links and/or O-D paths experiencing the most significant volume and/or travel time increases as a result of the modeled growth.

TEST Results: Des Moines, Iowa

Des Moines, Iowa, and the several communities surrounding it, comprise Iowa's largest urbanized area. The total population of this area is approximately 450,000. Presently, Des Moines meets all CAAA air quality standards. The Des Moines Metropolitan Planning Organization (MPO) uses Tranplan to model the travel demand of the region. The Des Moines MPO provided a copy of their 1990 calibrated model, which consists of 643 TAZs and external stations.

Table 1 presents the results of a 20% increase in traffic above 1990 levels for the four growth scenarios. The 20 percent traffic growth could have resulted, say, from a 20 percent increase in population. It is important to note that we use a 20 percent growth in trips, rather than VMT, due to the nature of the travel model. However, trends in trip lengths reveal modest changes (work trips modestly longer; other trips, modestly shorter, FHWA 1992). Assuming no bias in trip length distribution, the 20 percent increase in trips would produce a 20 percent increase in VMT.

The worse case travel-increasing scenario (assuming the "more of the same" development), scenario four, increases delay only 7.4 percent. Assuming that persons and activity center location decisions are highly sensitive to travel conditions (scenario 3), delay increases by only 2.8 percent. The other scenarios (1 and 2) are in the 3 to 4 percent range.

TABLE 2.1: Distribution of 20 Percent Travel Growth in Des Moines, Iowa

Distribution	% VMT Increase	VHT (A)	Delay, hrs (B)	Delay, % (B/A)	Change in Delay, %	Congestion Index (RI)*
Base (Existing)	-	206006	12201	5.9	-	0.07
Uniform	20.4	259796	24626	9.5	61	0.12
Random	19.3	256231	23338	9.1	54.2	0.11
Uncongested	18.5	253455	22209	8.8	49.2	0.11
Congested	25.8	287243	38145	13.3	125.4	0.18

* Tranplan Output (comparable to % Delay).

Conclusions

We have essentially made two points about VMT growth. One is that automobilization has essentially run its course, and it makes no sense to regard VMT growth in a "doomsday, national crisis" fashion. That's not saying, of course, that one need not be concerned about issues of congestion, fuel consumption, emissions, etc., it just lends perspective to those issues. How does that "no doomsday" situation spell out at the regional-metropolitan level? It spells out differently for each area, of course. We looked at Des Moines, which is not Los Angeles, but is representative of many of the Nation's medium-size urban areas. Our point from that view is that impacts depend on the places traffic appears. In comparison to the worse case, adding traffic where congestion already exists, there are other plausible cases yielding much more limited impacts.

Where does this lead us? Perhaps it suggests the need for more flexible policies that shy away from the rigidities imposed by imagining ever increasing and unmanageable VMT growth. This is particularly critical, in the context of this paper, when applying national VMT policies equally to those areas that have projected an aging population and to those that have high immigration and a growing birth rate. Perhaps it suggests re-looking at the UTPS process. Should trip generation models be modified to be more sensitive to underlying trends affecting travel growth? Nowadays, much improved information systems of a GIS-type might well allow tying land use forecasting to VMT policy, as well as to the ways markets are evolving as evidenced by such things as building and subdivision permits. Perhaps that is the task, the evolution of the UTP system in light of today's conditions and capabilities.

CHAPTER 3. DEVELOPMENT AND APPLICATION OF A GIS-TRAVEL DEMAND MODEL INTERFACE FOR TRANSPORTATION ALTERNATIVES ANALYSIS

Introduction

For at least seven years researchers have recognized the potential for application of GIS in transportation planning and modeling [Fletcher,1987]. Effective application of GIS for transportation modeling requires the integration of GIS and travel demand models. Three primary integration strategies have been identified [Shaw,1993]:

- Developing interface modules between GIS and separate travel demand modeling systems.
- Developing a specific modeling system that includes partial GIS capabilities, while both parts recognize each other's data models.
- Developing a full GIS with partial modeling capabilities.

Some consider the modeling-oriented GIS to be the most feasible and effective approach to integrating transportation planning models with GIS. Several successful transportation planning applications have been developed which utilize a transportation-modeling oriented GIS [Hartgen,1992]. The primary shortcoming of such as system, however, may be its inability to integrate different types of modeling applications within a single GIS environment [Shaw,1993].

Another strategy that has received much attention is the development of an interface between a GIS and a separate travel demand system ([Barrett,1991], [Niemeier,1993], [Kriger,1991]). This strategy has been criticized because it may introduce data redundancy, and because it may not satisfy everyone's concept of system integration [Shaw,1993].

Motivation

A modeling-oriented GIS will provide the integration of a specific modeling application (e.g. travel demand modeling) within a GIS environment, but will it foster overall data, software, and hardware integration within and among institutions? Modeling-oriented GISs are developed for very specific applications, potentially limiting additional application capabilities. Many transportation agencies have devoted significant time, effort, and capital identifying and implementing specific hardware and software platforms within their agencies. These platforms may include databases, computer aided drafting (CAD) systems, transportation modeling systems, and GIS. In the long run, the integration of existing data sets and computer systems, including GIS and transportation modeling systems, may be more effective and feasible than the within-system integration that application specific GIS packages provide. Agencies must decide whether to invest in multiple application specific GIS packages or to fully utilize and integrate the hardware and software that it already owns and operates. Furthermore, federal mandates (e.g. ISTEA) calling for the integration of diverse information and the participation of various governmental agencies in transportation planning warrant maintaining data in formats which are easily integrated and transferable. Application specific GIS packages may introduce yet another data format into an institutional system already struggling to manage multiple data formats.

An interface between a GIS and a separate travel demand modeling system is one way to demonstrate the capabilities, shortcomings, and potential benefit of such an integration strategy.

Simply developing and implementing an interface is too broad of a scope. Therefore, the GIS-travel demand model interface must be developed for a specific purpose or application.

Scope and Objectives

The primary objective of this chapter is to describe the development and application of a prototype GIS-travel demand model interface (using Intergraph's MGE/MGA and Urban Analysis Group's Tranplan software[1]). The interface can be used to enhance transportation planning through real time analysis of transportation planning alternatives. A case study is presented for Des Moines, Iowa.

The chapter scopes proposed system application, platform selection, creating a transportation network in a GIS environment, data integration, and development of alternatives analysis capabilities. Issues involved in system development, limitations and capabilities, and early system application are also discussed. While some of the concepts and findings presented in this chapter are hardware and software specific, they could extend to many GIS-travel demand modeling environments.

Real Time Analysis of Transportation Planning Alternatives

A multi-layer thematic map graphic will improve the users' ability not only to modify data and assumptions, but to recognize the implications of changes through overlay of input and output networks. The user should be capable of performing the following data and assumption modifications:

- network attribute changes (e.g. increasing the capacity of a roadway)
- network spatial modification (e.g. adding new links)
- spatial aggregation of features affecting demand (e.g. TAZ boundaries)
- demand attribute modifications (e.g. TAZ and landuse data)

The computing capabilities of workstations and high-end workstations personal computers reduces the time required for running the transportation planning model, facilitating the interactive viewing of outputs resulting from changes in assumptions and data.

Creating a Base Transportation Network in the GIS Environment

Utilizing Existing Tranplan Data Sets

The first stage in the development of the model interface includes creating a transportation network in the GIS environment. This process can be a significant undertaking. For example, using Intergraph's MicroStation (computer aided design and drafting software), MGE, MGA, and IRASC (which interfaces MGE/MGA and a database), the Minnesota Department of Transportation (MnDOT) embarked on the $1.8 million task of completely redesigning and updating the Seven-County Metropolitan Area's regional transportation model [Barrett,1991]. The model interface described here was not intended to require a comprehensive redesign of a transportation model. Existing Tranplan data sets, particularly link and node records, were to be utilized to create the transportation network within the MGE environment.

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[1] Appendix A describes each of these systems and explains why they were selected.

Even though Tranplan data sets, instead of digital cartographic maps, were used to develop the transportation network, procedures and software developed by MnDOT were applicable.

Creating an MGE Project

MGE organizes all data corresponding to an operating system (CLIX) directory, or related data sets, as a project [Intergraph (MGNUC),1993]. If an existing MGE project contains data relevant to the study area, it may be appropriate to use the existing project. If no relevant data exists, a new project should be created. Initially, data sets were only immediately available for a Des Moines Tranplan model; therefore, a new MGE project was created.

The new MGE project was created using the *Create* option located in the MGE Project Manager. After the project was created, a new RIS schema (database pointers and parameters) was created through *RIS Schema Manager*. Using *Define Project Schema*, the new schema was associated with the new project. Thematically or geographically related maps, as well as features, are grouped according to categories, such as transportation, hydrology, and parcels. Since the only data initially included in the project was transportation related, a single category called 'transportation' was created using *Category Builder*. New categories could be created whenever additional data is incorporated into the project. Lastly, features and database tables were built with *Feature/Schema Builder*. Features are sets of graphics identified by user specifications, such as category, line width, and color, and may represent various entities such as functional classification of a roadway or the number of lanes of a roadway.

Defining Features

Seven features were originally created for the Des Moines project. These features included linear graphic elements representing links in the Des Moines transportation network and point elements representing nodes and zone centroids. Link features were defined as either a centroid connector or one of four unique functional classes of roadway. The link features were associated with an attribute table similar in format to a Tranplan link data record. Pertinent data from a link record include: "from" node (a-node); "to" node (b-node); assignment group (used in loading); link distance; (free flow) directional speed and/or time; (loaded) directional speed and/or time; link groups (used to group links with common characteristics); directional volume and/or capacity; and one-way/two-way notation (See Figure 3.1).

An attribute table was also associated with the node features. The only data required in the node attribute table were the node numbers, x-coordinates, and y-coordinates.

Setting Up Reference System

Following development of features and attribute tables, a MicroStation seed file was created. A seed file is a template used to create all new design files, ensuring that all maps created in a project use the same reference system. Using *Design File Setup*, the user may create a seed file for 2-D and 3-D, projected and nonprojected coordinate systems [Intergraph (MGNUC),1993]. Since MicroStation graphics were to be created using Tranplan data sets, it was necessary to determine the coordinate system, projection, and units used to create the Tranplan data. Documentation of the Des Moines Tranplan model revealed only that the model was developed using State Plane Coordinate System 1927, Iowa South Zone. The primary coordinate system for the seed file was defined using this information only. Feet were defined as the working units, and the global origin was set to coordinates 0,0.

Database Set Up (ORACLE)

Although link and node attribute tables already existed, in order to create graphics and move Tranplan and ORACLE data, two temporary ORACLE tables, near duplicates of the link and node attribute tables, were created. These tables were created with SQL statements and were not linked to graphics. Both the temporary tables contained a column called MSLINK (a unique reference number for each record). The MSLINK column enables a row to be linked to a graphic element. MicroStation uses the MSLINK column to identify the rows linked to graphics. The MSLINK column must contain a value for MicroStation graphics to be created. A SQL statement updated the MSLINK columns of the two tables, and ORACLE's *sqlload* function loaded the Tranplan node and link data (in ASCII format) into the temporary tables.

Creating Graphics: Nodes with Full Attribution

After the temporary tables were populated, the schema was attached to a new design file (a copy of the seed file) using the MicroStation *active database* command. This must be done so that nongraphic data can be manipulated in MicroStation [Intergraph,1991]. A node creating program written in MicroStation's User Command macro (UCM) language then created text nodes.

The user initiates the node creating program from the MicroStation prompt (USTN>). The program asks for the total number of nodes in the network and the total number of centroids. The program reads the node number, x-coordinate, and y-coordinate from the temporary node table, converts the coordinates to design file format, and places text nodes (a node and an attached number) in the design file. Because centroids always occur first in a Tranplan node data file, and the user inputs the number of centroids to expect, the program will place centroids in the design file on a different layer from other nodes (intersections) with a unique symbology (color and size), facilitating visual differentiation between zone centroids and other nodes.

Immediately after the elements were created, they had no linkage to the database. Therefore, a feature linkage was attached to each element. *Feature Maker* tags an element as a feature based on one or more element properties. Because the two node types were placed on different levels, the level of an element specified which feature the element was to become. Blank records (with an MSLINK value) were loaded into the node attribute table.

A second UCM program populated the database. The program located each feature-linked text node in the design file and wrote the node number, x coordinate, and y coordinate in the node attribute table (See Figure 3.2).

Creating Graphics: Links with Partial Attribution

The links in the network were created in a similar manner as the nodes. A UCM program read the a-node, b-node, and assignment group (or functional classification) from the temporary link table. The program searched the node attribute table twice to get the x-coordinate and y-coordinate for each link's a-node and b-node and then converted the coordinates to design file format. The program verified that the functional classification values were valid, based on program specifications (e.g. a numeric code), and drew a line between the a-node and b-node coordinates. The symbology and level of each link was defined by the functional classification value.

Feature maker attached a feature linkage to each elements. Since roads with different functional classification were placed on a different level, the level an element was on specified which feature it was to become. Blank records (with an MSLINK value) were loaded into the link attribute table, and features were redrawn to match the correct feature symbology (e.g width, color, level, and style).

A final UCM program populated the database. The program examined each link feature in the design file, calculated its distance, identified its node endpoints, and determined its a-node, b-node, and facility type. The a-node, b-node, distance, and facility type were then written to the link attribute table (See Figure 3.3).

Populating Link Records

Based on the a-node/b-node notation (e.g. the a-node value is always less than the b-node value) the remaining link data was populated. Data from the temporary table was copied to the attribute table using a SQL statement which joined the two tables based on the a-node/b-node notation.

The UCM program, which initially populated the link attribute table, populated the database with a-node values less than b-node values. Because the a-node value may not always be less than the b-node value in Tranplan data sets, the data in the temporary table, specifically the a-node and b-node notation, had to be manipulated to replicate the notation in the link attribute table. A SQL statement moved the a-node to b-node and the b-node to a-node whenever the a-node value was greater than the b-node value. The data representing the a-node to b-node movement was also manipulated to represent the b-node to a-node movement, and visa versa.

Modification of the initial format of the Tranplan data was also necessary. The Minnesota DOT system (the model for the Des Moines MGE project) utilized unique notation to represent the directional characteristics of a link. Two columns in the link attribute table were dedicated for this notation. An S/S combination represented a two way link; a S/T combination represented a one-way link from a-node to b-node; and a T/S combination represented a one-way link from b-node to a-node. This notation is different from the notation required by Tranplan. MnDOT used the notation because it seemed to better facilitate the exchange of data from Intergraph to Tranplan, lessening the computational requirements of the exchange. Since the two column notation was used for the Des Moines MGE project, the data in the temporary link table were placed in this format (using a SQL statement) before it was copied to the link attribute table.

Topology

Using *MGA Topo Builder* point and line topology was built for the network. Topology is defined as the spatial connectivity and adjacency of point, area, and line features. Topology must be created before spatial queries can be executed. A list file, which identifies design file elements and their attribute linkage information, was created before topology was built [Intergraph (MGA),1993].

Issues Involved in Creating the Base Network from Tranplan Data

Feature Definition

Because most Tranplan networks are coded differently, the UCM program which created the linear elements may need to be modified for each new Tranplan data set. Data contained in columns other than the assignment group column, such as a link group, may be used to group homogeneous links. For example, links in the Des Moines model were created using "number of lanes" to define their feature type. Although elements were placed on different levels, most were not the correct feature. The feature type of many of the links was redefined using *Feature/Attribute Manager*. Similarly, substantial feature coding would be required if all elements were placed on the same level, with the same symbology.

Tranplan Spatial Data/Data Integration

Travel demand model networks need not be spatially accurate. In fact Tranplan node coordinates need not represent real world coordinates at all. For example, the Tranplan node coordinates for Des Moines were approximately 52.8 times less than the actual State Plane coordinates. Because of the coordinate discrepancies, the node coordinates had to be converted to more representative State Plane coordinate values before the MicroStation graphics were created. In instances where Tranplan node coordinates are totally arbitrary, the coordinate data may need to be manipulated so that the graphics can at least be created in a seed file. This must be done to facilitate the overlay of other graphic data sets.

Most travel demand models, as in all link-node network specifications, represent curvilinear roads as one or more straight line segments, and part of the transportation network is represented by nodes (e.g zone centroids) and links (centroid connectors) which do not exist in the actual transportation system but are used in modeling. A single model link may also represent more than one road in the actual transportation system. Additionally, centroid connectors intersect model links at locations where actual intersections do not exist.

These factors as well as model spatial inaccuracies may make the integration of Tranplan spatial data with other spatial data quite difficult. The spatial data sets will most likely not align properly, and one-to-one elemental correspondence between links of the spatial data sets will not exist. If one-to-one element correspondence exists, conflation (a GIS method of transferring data tied to one map to another map) may be used to merge the Tranplan data with other spatial data, such as a cartographic digital map. Unfortunately, the process of establishing one-to-one correspondence can be a significant undertaking.

One-to-one data correspondence is accomplished through geometric cleanup and merging or splitting of line segments. Feature densification (placing additional vertices in line segments) and lateral/longitudinal adjustment of geometry may also be necessary to assure accurate information is provided for merging. In a demonstration project attempting to conflate TIGER graphics (the Census Bureau's Topologically Integrated Geographic Encoding and Reference system) and Maryland State Highway Administration data, nearly half of the total operator time was devoted to establishing one-to-one data correspondence. Another 30 percent of the total operator time was devoted to resolving unmerged features, which represented only six percent of the total features (unpublished data).

An alternative to establishing a one-to-one correspondence between Tranplan-based graphics and a digital, cartographic map graphics, is to manipulate the existing Tranplan-based graphics to better replicate a digital map. This may entail lateral/longitudinal adjustment of nodes and line segments, extending line segments, and densifying line segments. All attribute data will remain attached to the features in this process. One design file will represent the travel demand model network, while other design files may represent spatial data about the network as a whole.

Link Attributes

Because all links in Tranplan are represented as straight lines, the actual geometry (therefore, length) of some roads can not be accurately represented. This can be accounted for in Tranplan by adjusting link distance values. A link distance which is longer than the actual straight line node to node distance may be used to represent the actual distance of the link.

When a link is created with the UCM program, the actual straight line distance of the linear element is automatically calculated and placed in the link attribute table. This link distance value may not be the same as the Tranplan link distance; therefore, it may be appropriate to load distances directly from Tranplan data sets. If the Tranplan-based graphics are manipulated to better represent actual link geometry, actual link distances may be recalculated and loaded into the link attribute table.

Duplicate Elements

Duplicate nodes and links (nodes or links on top of each other) may exist in Tranplan data files. The UCM which populates the link attribute table does not recognize duplicate nodes and links. Before graphics are created, a SQL statement should analyze the temporary node file to insure that duplicate nodes do not exist.

Data Integration

Utilizing Other Tranplan Data

All pertinent Des Moines Tranplan data sets were first integrated with Tranplan-based spatial data. These data sets included the turn prohibitor records and zonal production/attraction records.

The first step in integrating the additional Tranplan data sets with the Tranplan spatial data involved creating a new ORACLE table for each data set. New tables, not linked to graphics, were created using *Feature/Schema Builder*. ORACLE's *sqlload* function loaded the Tranplan data (in ASCII format) into the appropriate tables.

Relational joins were created (with *Join Manager*) to associate the new data sets with an existing graphic-linked tables (link and node). The turn prohibitor attribute table contained three node values that could be joined with the node attribute table. The node values stored in the turn prohibitor table represent the following: 1) the node from which the prohibited turn originates, 2) the node through which the prohibited turn passes, and 3) the node at which the prohibited turn terminates. The "through" node was used for the join (See Figure 3.4).

Zonal production/attration data was also joined with the node attribute table. The production/attration data are stored by zone centroid; therefore, the zone centroid was associated with the node number of the node attribute table. Zonal trip generation data could be joined in the same manner.[2]

After the two relational joins were created, relational views were defined using *View Manager*. A relational view combines tables so that they appear to be a single table. A view must contain a primary table that is attached to graphics or a join relationship containing a primary table linked to graphics. A view may be used in both spatial and attribute queries, but the data in a view can not be modified [Intergraph (MGAD),1993]. Two views were created for Des Moines: a turn prohibitor view and a production/attraction view. The columns included in the view were defined by using the joins that had been previously created.

Database Records: AADT

Other tabular information may also be integrated with the Tranplan spatial data. The data, however, must be in ASCII format and share a common attribute with a table already existing in the database in order to be joined.

The Des Moines Metropolitan Planning Organization (MPO) maintains a database containing average annual daily traffic (AADT) data for many of the roads represented in the Des Moines Tranplan model. In addition to the AADT counts, the database includes street names, the Tranplan a-node and b-node of the streets, the cross streets, and the year the counts were taken. The a-node and b-node contained in the database correspond directly with the a-node and b-node of the original Tranplan network. Therefore, these data could be easily integrated with the existing link attribute data in the MGE environment.

Several strategies could have been utilized to integrate the data. The simplest strategy would have been to create an Oracle table consisting of all of the data and join the new table with the link attribute table. A different, slightly more involved, approach was used to integrate the AADT data so that street names and the most current ground counts would also be stored in the link attribute table.

First, a temporary Oracle table was created. This table included column definitions for a-node, b-node, AADT count, year during which the count was taken, street name, and a column to be used to manipulate the a-node/b-node notation. ORACLE's *sqlload function* loaded the appropriate data from the ASCII file into the temporary table. A SQL statement then manipulated the a-node/b-node notation to match the a-node value less than b-node value of the link attribute table. Using *Feature/Schema Builder* a road name column was added to the link attribute table. A SQL statement joined the a-node/b-node of the link attribute table and temporary table and populated the road name column.

Unfortunately, the road names in the ASCII file were not in a consistent format. Many road names either were preceded by spaces or contained multiple spaces in their names. This

[2] Modal split was not a factor in the Tranplan model utilized; none-the-less, it is important to note that Tranplan transit data can be integrated with Tranplan-based spatial data. A Tranplan transit network is defined primarily on a link-by-link, line, and node basis. Transit links can be joined with the graphic link attribute table based on a-node/b-node notation. The common attribute between the transit link table and the transit line table is a unique mode identification. The transit line data can be joined to the transit link table with the mode attribute. The mode attribute can also be used to join the transit line table with the link attribute/transit link join. Transit nodes can be joined with the node attribute table.

format was passed to the temporary table and then to the link attribute table. Because text string queries must match exactly, the road name format did not readily facilitate database queries. Therefore, all road names preceded by spaces or containing multiple spaces were updated using SQL statements.

The next step to integrating the AADT data required creating a permanent ORACLE table. The table was to provide a yearly ground count data on each link and included columns for a-node, b-node, directional notation, and AADT counts specified by year and direction. Since the a-node/b-node notation had already been manipulated in the temporary table, ORACLE's *sqlload* function loaded the a-node/b-node values directly into the new table. A SQL statement loaded the directional notation values from the link attribute table. A SQL statement was then used to transfer the AADT count data into the appropriate columns. The data transfer was defined by two conditions: directional notation and the year of the count. If the directional notation specified that a link was two-way, the AADT count in the temporary table was divided by two and placed in the a-node/b-node and b-node/a-node columns for the appropriate year. If the directional notation specified that a link was one way, the full AADT count value was placed in the appropriate a-node/b-node or b-node/a-node for the appropriate year.

Further Utilization of AADT Database Records

After the all the links with road names were updated, all links with a road name were displayed using a query built with *MGA Query Builder*. The links not possessing an associated road name were easily identifiable. Many of these links were located between links possessing an associated road name. When the road name of an adjacent link was known, the links missing a road name could be easily coded. Two strategies were utilized to code road names for part of the Des Moines network.

Adjacent links were identified using the MicroStation *rev* command or *GeoDatabase Locate*. When only one link in a road did not have a road name, the road name of the uncoded link was updated with *GeoDatabase Locate*. If several links in a road were without road names, a fence was drawn around the entire road containing links to be updated. The fence was defined to include only those elements entirely within the fence. Of these elements only the links in the fence without a road name were selected (See Figure 3.5). This was done using a MicroStation database criteria search (*ds*), in SQL language. The MicroStation *el* command created a list file (identifying graphic elements and their attribute linkages [Kriger,1991]) of only the selected links, and the road name of the links in the list file were simultaneously updated with *Bulk Update*. Using this strategy and a street map with names, all links in the network were coded with a road name.

MapInfo Data

MGE's ability to directly exchange data between MGE and MapInfo, a PC-based desktop mapping system [GIS World,1994], created another opportunity for data integration. The Des Moines MPO is beginning to utilize MapInfo to present, manage, analyze, and integrate some of its graphic data. They provided two relevant MapInfo data sets, travel analysis zones (TAZ) and land use definitions.

Prior to downloading the MapInfo data and placing it in the appropriate project directory, the data were converted (in MapInfo) to the Iowa South Zone State Plane Coordinate System.

Two additional features, each associated with an attribute table, were then created in *MGE Feature/Schema Builder*. Both of these features were areas features, one representing TAZ boundaries and one representing land use boundaries. A parameter file was created to define the translation. Two copies of the seed file, to bring the graphics into, were also created. The actual data translation was performed with *MapInfo Translator*. Unfortunately, the MGE version used for the translation did not convert the data properly. The TAZ and land use boundaries, which were regions in MapInfo, were converted to closed line strings and complex strings in MicroStation. Because of this, area topology could not be built. Furthermore, the graphics were not placed correctly in the design file. The 5.0 version of *MapInfo Translator* should correct these problems.

Following the MapInfo translation, the graphic line work will need to be cleaned before topology can be built. *MGA Patterner* can create a design file with land use areas patterned, hatched, colorfilled, and crosshatched based on land use type. Otherwise, land use areas are represented by simple line work (polygons). Additionally, since the land use attribute table also contains jurisdiction data, all land use shapes with common jurisdiction may be merged, with *Area Merger*, to create a design file of jurisdictions.

TIGER Data

An attempt was made to integrate the U.S. Census Bureau's Topologically Integrated Geographic Encoding and Reference (TIGER) files with the Tranplan base data. Specific MGE software is required to translate the TIGER data.

Since the Tranplan-based graphics were created first in the Iowa South Zone State Plane Coordinate System, the TIGER data must be converted to this coordinate system. The TIGER graphics will be used as the reference base map to which the Tranplan and MapInfo graphics will be manipulated to fit.

Development of Alternatives Analysis Capabilities

Creating a New MGE Project

Alternatives analysis requires management of the spatial and attribute changes made to a baseline transportation network, in this case, the Des Moines Tranplan-based network. One method, introduced by Barrett [Barrett,1994] and used here in the creation of more than one MGE project. If only attribute data were to be manipulated, multiple projects would not be necessary. Changes in network attributes could be represented by data stored in additional columns in database tables. However, it is desirable to have the ability to manipulate spatial data as well.

In order to display network changes, a separate MGE project to store additions, deletions, and changes is required. Therefore, the first step in this process is to create a new MGE project. The new project, in this case, was an exact copy of the original Des Moines project with one primary difference; the data in the new project were to be accessed by a new user, facilitating data management (See Appendix A, System Description: Intergraph). Therefore, both a new UNIX user and a new ORACLE user are created. A new project and schema are created as the new user, and the new schema is associated with the new project. As the owner of the original project, the original project is exported using *Export Project*. The new user then imports the project into the newly created project with *Project Import.* Unfortunately, creating a second, duplicate project also introduces data redundancy.

Modifying Spatial and Attribute Link and Node Data

All spatial or attribute changes are made in the new project. Those changes directly involving the link and node attribute tables included: adding, deleting, and modifying/moving links and nodes and modifying link attributes.

Deleting links/nodes and moving nodes are straight forward. The MicroStation command, *set delete on*, is utilized to delete not only the element but also the row corresponding to the element in the database. Nodes are moved using the *move element* command. A UCM program updates the x-coordinate and y-coordinate of the nodes.

Link elements are modified, usually extended, with the MicroStation *modify element* command. A UCM program automatically updates the modified link's record in the link attribute table. This program, however, was developed with default values, such as functional classification, for Minneapolis/St. Paul. The program may be modified for the Des Moines project or simply modified to only populate the a-node, b-node, and distance values. Otherwise, link attributes (records) are manually entered using *Feature/Attribute Manager*.

New links/nodes are digitized by feature type using *Digitize* and *Place Feature*. After a feature is created, *Digitize Attribution* creates a new row in the appropriate attribute table. The x-coordinate and y-coordinate of nodes are populated by executing a UCM program. These coordinates may also be manually populated. Link records are populated in either of the two methods described previously.

Managing Network Changes within ORACLE

Because only the new network is modified, network differences (with regard to links and nodes) are determined by comparing the link and node attribute tables of the old and new networks. Before the networks can be compared, both the new and old user have to be given 'select' privilege on each others link and node attribute tables. This is necessary so that SQL statements can locate all of the changes from one network to another. Five new ORACLE tables of data (deleted nodes, added nodes, deleted links, added links, and links with attribute changes) are created, with a SQL script, to store the results of a network comparison. Moved nodes are stored in both the added and deleted node tables because although the node has not actually been deleted, it is in a completely new location.

A single SQL statement locates the differences between the original and new network and populates the new ORACLE tables with the pertinent data. Nodes which were added to the new network are identified by selecting all node numbers in the new network and removing all the node numbers from the original network. When all the node numbers in the old network are selected and all the node numbers in the new network are removed, the only nodes that are remaining are those that were in the original network and not in the new network. The same concepts are used to locate added and deleted links.

When the node attribute tables are compared, the x-coordinate and y-coordinates of each node are also checked. If these values do not match for a given node, that node is written to both the added and deleted node tables. Finally, attribute changes from one network to another are located by selecting all links which have the same a-node/b-node but have different attributes, such as a speed and capacity.

Managing Network Changes with Design Files

An accurate comparison of the original and the new network requires creating the graphics associated with each of the five tables. This is necessary because elements in one network may not exist in another network. A design file must be created for each of the five changes that can occur between the original and the new networks (e.g. deleted nodes, added nodes, deleted links, added links, and links with attribute changes). However, only two new design files are necessary: one representing new and modified elements and one representing deleted elements.

Using MGE Feature/Schema Builder, a new column was added to the new and original projects' link and node attribute tables. This one character column represents whether an element has been added or deleted or has experienced an attribute modification. In ORACLE the user that owns the original project was granted 'select' privilege on the new user's deleted nodes and deleted links tables. The user may then access and extract data from the new project but is unable to modify the data. In the new project, a SQL statement updates the new column of the link attribute table based on whether a link is new (located in the added links table) or has experienced an attribute modification (located in the attribute changes table). The node attribute table is also updated if a node is new/moved (is located in the added node table). In the original project, a SQL statement updates this column of the link attribute table if the link has been deleted (located in the deleted node table). The node attribute table is updated if a node has been deleted/moved (located in the added node table).

Using *MGA Query Builder* in the original project, all links from the link attribute table that have been deleted graphically are selected. A design file of the resulting query is then built with *MGA Design Builder*. Another MGA query selects all nodes from the node attribute table that have been deleted. A design file is created for these query results as well. A copy of the seed file is made by the analyst, and the two design files created from the MGA queries are merged using MicroStation's *Merge* utility.

Line and point topology are then built for the new network (using *MGA TopoBuilder*.) The same procedure that is used for the original project is utilized for the new network. Design files are created for MGA queries which select the links which have been added, nodes which have been added/moved, and links which have experienced attribute changes. This yields three new design files which are merged (using the MicroStation *Merge* utility) to create a design file of new or changed elements. Since each of the new and changed elements are present in the modified network, the MGA queries alone could be used to display the new and changed elements. By creating new design files, duplicate graphic elements are created.

Developing an Interface between Intergraph GIS and Tranplan

Tranplan to GIS Interfaces

When Tranplan data sets are used to create spatial data in the GIS environment, the Tranplan data sets are transferred to the GIS via one-way interfaces. For example, the Des Moines node, link, turn, and production/attraction records were transferred using one-way interfaces. These interfaces are typically used only once.

A Tranplan to GIS interface consists of three primary components: Tranplan data in ASCII format, an ORACLE table in which to load the table, and an ORACLE *sqlload* statement which reads the ASCII data and loads it into the specified column of the table. A unique *sqlload* statement is required for each data type. Tranplan to GIS interfaces are also utilized in the two-way interfaces required for alternatives analyses.

Two-Way Interfaces

Development of a two-way interface begins with determining which data are to be exchanged between platforms, likely Tranplan output and data stored in ORACLE tables. When multiple projects are being used to manage alternatives, another consideration is which project's data is to be transferred. The simplest way to transfer data is to use only one project, typically the new/modified project. However, since the original network will always be a point of reference, the original link and node data should be transferred as well. This will eliminate the need for an entirely new network to be created after each network modification.

Data stored in ORACLE tables are transferred from an ORACLE format into an ASCII file format using Oracle's *spool* command. A separate SQL *spool* statement is required for each table. For the Des Moines project, the link, node, turn prohibitor, and production/attraction tables are converted to ASCII format. FORTRAN programs then read the ASCII files and create control files and data files in Tranplan format. For instance, a FORTRAN program was written that uses the Des Moines node and link files to create a Tranplan BUILD HIGHWAY NETWORK input and control file. Another FORTRAN program modifies the turn prohibitor file and places it in Tranplan input format. These new data files serve as input into the Tranplan module BUILD HIGHWAY NETWORK. The production/attraction spool generated file are modified by a third FORTRAN program to be input into the Tranplan GRAVITY MODEL module. Yet another program creates an UPDATE HIGHWAY NETWORK[3] control file in Tranplan format. This file is based on the data contained in the deleted link, deleted node, added link, added node, and modified node tables. The UPDATE HIGHWAY NETWORK module uses an existing highway network (binary format) as its input and creates a new network based on the changes identified in control file.

After FORTRAN programs have created Tranplan format files, the files are moved to a PC or workstation on which Tranplan resides. The files may be transferred from the Intergraph workstation using the internet or a floppy disk. Another workstation disk may also be mounted on the Intergraph workstation. When the files are created on the Intergraph workstation, the other workstation may access them automatically. Not all data needed by Tranplan are transferred to the Tranplan-dedicated PC/workstation. Most of the Tranplan control files and several of the data files may not reside on the GIS workstation. These data files are likely to be those that can not be geographically referenced, such as friction factors. However, this data may

[3] The UPDATE HIGHWAY NETWORK module uses an existing highway network (binary format) as its input and creates a new network based on the changes identified in control file.

be stored, manipulated, and managed using the relational database. Control files may also be created on the GIS workstation.

Once the Tranplan control and data files are accessible by Tranplan, the appropriate Tranplan modules may be executed. The end result of the Tranplan modules, specifically the network loading (assignment) modules, is a loaded highway network file (binary format). A Tranplan utility called, NETCARD, converts this file, which contains new link attribute data, to an ASCII format. An ORACLE *sqlload* statement copies the ASCII data into a temporary ORACLE table. Another SQL statement joins the temporary table with the original link attribute table (based on a-node/b-node notation) and transfers the new speeds and volumes to the link attribute table.

SQL statements can compare the attributes between the original and new network and populate columns in the link attribute table with the results. These columns may then be utilized to display the results graphically with MGA queries.

Proposed Application

Through the use of two networks, the effect of various transportation alternatives can be analyzed. For example, different alignments of a proposed bypass or system improvements may be examined. Additionally, the sensitivity of trip assignments to modifications of travel pattern assumptions (i.e. friction factors) and regional growth assumptions may also be analyzed. Furthermore, other Tranplan output, such as path data, can be manipulated and loaded into the relational database for display. Certain Tranplan output of interest, however, have yet to be integrated into the GIS environment. This includes origin-destination pairs.

MGA query sets and SQL statements are effective means of displaying the effects of various alternatives. The results of these queries can be saved as MicroStation design files, which eliminates the need to store essentially redundant data sets. Design files can be used to graphically present complex information in an understandable manner.

Conclusions

Developing an operational interface between a GIS and travel demand modeling software is involved. Initially, considerable time and effort must be devoted to establishing a GIS environment which facilitates the exchange of data between the GIS and travel demand model platforms. The interface discussed in this chapter utilizes existing Tranplan data sets to create such an environment.

In general, making use of existing data is one of the best ways to introduce the cartographic and analytical capabilities of GIS to transportation planning and modeling. Unfortunately, the spatial inaccuracies of travel demand networks may hinder the integration of more accurate cartographic data.

The GIS-travel demand model interface serves a medium to integrate the capabilities of each individual platform. The GIS provides extensive data management, display, and spatial analyses capabilities, while the travel demand model executes mathematically and computationally intensive modeling routines. A high speed computer, which can execute these modeling processes quickly, provides the opportunity for real time analyses of transportation alternatives. GIS is the platform through which the alternatives can be created and displayed.

Today, development and application of an interactive GIS-travel demand modeling system requires extensive knowledge of several software platforms. The system is powerful and creates new opportunities in transportation planning. An experienced transportation analyst can easily generate and analyze multiple, data intensive transportation problems using the system. The display capabilities of GIS provide decision makers with more readily understandable explanations of complicated issues. Furthermore, utilizing GIS and travel demand modeling platforms which are widely used, may best facilitate intra- and inter-institutional data integration.

CHAPTER 4. THREE APPLICATIONS OF GIS FOR TRANSPORTATION PLANNING AND NETWORK MODELING

introduction

The potential for effective use of GIS for planning government operations and facilities has been suggested in several strategic planning efforts of State Transportation Departments (Pennsylvania, Iowa, Wisconsin, Maryland to name a few.) In these efforts, hundreds of applications have been identified, ranging from support of Pavement Management and other ISTEA mandated management/monitoring systems to sign inventory, roadway inventory, and videologs. Many of these efforts, however are still in early stages of development and few if any represent fully deployed, department-wide integrated systems. This is due to the complexity of introducing GIS in such environments where one may find databases several gigabytes in size, referenced by several location referencing systems and under the control or authority of many different offices with differing support missions. Because of such wide system management variability, early applications in transportation were focused on asset inventory and management, rather than planning.

Accurate estimation of future travel demand is an essential component of effective urban transportation planning. Assumptions and forecasts based on existing socio-economic data, land use, and transportation facilities drive estimates of future demand for travel. Urban travel among traffic analysis zones (TAZs) is commonly modeled using an urban transportation modeling system (UTMS). Typically, a UTMS is comprised of four modeling steps: 1) trip generation, 2) trip distribution, 3) modal split, and 4) trip assignment. Inputs include geometric and operational characteristics of the transportation system (network), available modes, and factors and data influencing trip generation. Parameters are also required to accurately model trip making behavior, such as the propensity to make shorter versus longer trips.

The process of creating an urban transportation network and a socioeconomic database is labor intensive and time consuming. Massive data collection and integration efforts are required. Furthermore, transportation networks are likely to be frequently modified. O'Neill lists three primary reasons for these modifications [1991]. First, network modifications may be warranted because of changes in land use and/or socioeconomic characteristics. Second, to suit specific applications and/or software constraints, zones, links, and nodes may be aggregated and disaggregated, thus changing the network. Third, transportation networks are often subjectively defined. Subjective decisions made by developers of the network may precipitate network modifications during the calibration process [O'Neill,1991].

Successful urban planning projects depend on effective communication of objectives and results. The spatial data processing, modeling, and effective display capabilities of GIS are useful features for transportation planners. However, many urban planning organizations do not yet fully utilize the potential of GIS. While GIS is used for data collection, manipulation and display, much more is possible. It is the objective of this chapter to identify, characterize, and suggest preliminary designs for some of these possible applications.

GIS for Transportation Planning

Although early GIS applications in transportation focused on asset inventory and management, information on the use of GIS for modeling by transportation planning agencies was not published until about 1990. Development of planning tools within GIS was introduced as early as 1986 [Lewis,1990]. About ten percent of current GIS literature (identified in a computer library search) relates to transportation. Of that, about half is devoted to transportation planning applications. From 50 articles on GIS for transportation planning, we have examined 10 that discuss applications of GIS for transportation network modeling. Relevant research has been conducted by Barrett [1991,1994], Blewett [1991], Choi [1993], Gallimore [1992], Hartgen [1992], Kriger [1992], Karakatsanis [1989], Lewis [1990], McAdams [1992], Nyerges [1992], O'Neill [1991], Replogle [1989], Simkowitz [1989], and others. Specifically, GIS has been successfully linked to travel demand models [Kriger,1991]. Regional planning models have also been created with GIS [Barrett,1991], and GIS has been used for transportation modeling [Hartgen,1992].

Some agencies, (metropolitan planning organizations, especially) have purchased GIS hardware and software, are developing databases, and are beginning to use the systems to provide inputs to modeling and decision-making. Based on discussions with planners in these organizations, the authors see three areas for further application of GIS in conjunction with transportation planning models. These applications are fostered by the increased availability of high speed computing environments and include:

- developing UTP models using GIS
- developing a GIS from a UTP model, and
- a high-speed interactive loop for analysis of alternatives and investigating the sensitivity of outcomes to policy options

Each requires a different flow of information and specialized software tools, but all are based on a linkage between GIS and an urban travel forecasting model. These applications are discussed in the sections to follow.

Choosing GIS and UTMS Platforms

GIS World identifies 147 GIS software platforms. The most popular packages, ESRI's Arc/Info, Intergraph's MGE, and MapInfo are used by over 250,000 persons and comprise more than 60% of the market [GIS World,1994]. Arc/Info is perhaps better known in planning and natural resource management agencies, whereas MGE is better known to engineers and public works/transportation departments.

Of those reporting at a recent GIS-T conference:

- 19 state transportation departments use MGE,
- 14 use Arc/Info,
- 2 use MapInfo,
- 4 use Graphic Data Systems (GDS), and
- 1 uses GIS Plus (Caliper Corporation). [unpublished data]

An informal survey of 20 metropolitan planning organizations (5 samples from each of four population categories) indicated the following applications of GIS software:

- For MPOs in areas greater than 5 million population, three use Arc/Info, one uses MGE, and the other uses MapInfo.
- For 1 million to 5 million, 3 use Arc/Info, one uses Atlas GIS and one uses MapInfo.

- For 200,000 to 1 million, three use Arc/Info, one uses Genasys, and one uses Atlas GIS.
- For MPOs in areas under 200,000 population, one uses Arc/Info, one uses GIS Plus, one uses a Census TIGER display tool and two do not yet use GIS.

While many GIS and platforms are conceptually similar, all are unique. That is, they may be highly specialized and may not easily accommodate all potential applications. Moreover, since GIS implementation requires extensive institutional and financial commitment, selection criteria must consider existing and future agency investment (hardware, software, personnel) and needs. Key factors influencing the selection of GIS platforms are:

- operating systems
- hardware requirements
- coordinate and referencing system capabilities
- data entry, data exchange formats
- database management, analytical functions
- network analysis capabilities
- user interface and data display
- output devices
- transferability of existing applications, and
- availability of data

Earlier work by the authors and recent publications indicate that Arc/Info, Geo/SQL [Kriger,1991] and GIS+/Transcad are viable environments for developing UTMS-based models. However, due to availability of hardware, software, and data sets for local transportation networks, Intergraph Corporation's Modular GIS Environment (MGE) was chosen as the GIS platform for the application areas investigated. MGE and MicroStation (Intergraph's CAD platform) are currently used by many agencies, including the Iowa DOT. (The Iowa DOT is currently in the process of selecting a department-wide GIS platform). Use of MGE would facilitate transfer of the applications to the Iowa DOT.

There are more than 12 software implementations of network assignment models based on the UTMS method, with the top three (Tranplan, MINUTP, and QRSII) comprising 74 percent of the market [Hartgen,1992]. Because of its widespread use and analytical capabilities, Tranplan was chosen as the UTMS platform. The Iowa Department of Transportation (DOT) and five of the seven Iowa MPOs currently use Tranplan, making calibrated transportation networks readily accessible. The widespread use of Tranplan also provides a market for future technology transfer.

The concepts and findings presented in this chapter, however, are not hardware and software specific. Many of the issues surrounding development of UTMS models, GISs linked to these models, and interactive tools for alternatives and policy analyses extend to any GIS/transportation modeling environment.[1]

Developing a UTMS Model Using GIS

By and large, metropolitan regions requiring UTMS based models have already built them for at least a baseline year and one or more future-year growth scenarios. What remains for

[1] Transcad is one GIS package that has been designed to address some of the data flow issues discussed in this paper. Other GIS vendors are currently developing or marketing transportation applications or modules.

these areas is to modify existing models to represent alternative patterns of infrastructure and land use development. Other areas have not yet built UTMS models. These areas include high growth regions which currently do not require sophisticated analytical tools, but soon will. Furthermore, meeting ISTEA statewide planning requirements may require developing models for new areas. For example, assessing the potential impacts of a by-pass on a small urban area may be facilitated by application of a UTMS type model.

Many agencies that develop or wish to develop network planning models possess CAD files of street networks (maps) that have graphic features but are not tied to a database. With MGE or other GISs, it is relatively straightforward to create the linework needed for a model from these maps. More complex is creating the link-based data needed by planning software packages. It is possible to semi-automate a procedure to convert graphical data into tabular data for this purpose. Such data might include line widths or colors that represent functional classification, symbols that represent speed limits or route designations, indications of number of lanes, access control, and average annual daily traffic (AADT). A problem exists when CAD file maps break road elements into links that are different than the links needed for the demand modeling process. (See Figure 4.1.) Additional difficulties may arise because CAD maps do not recognize link intersections as unique elements. Planning models (Tranplan), however, require information about these intersections to represent link endpoints and operational characteristics of the intersections.

Often, planning models use a higher level of aggregation than CAD files that were not designed with planning in mind. Further, not all links of a roadway system are modeled in a planning model. To automate the process, there must be some physical distinction between elements which are to be included and others which are not. Even if this distinction is made, not all elements required for a planning model will be present.

Planning models represent TAZs as zone centroids. All travel generated in a zone is assumed to originate from the zone centroid. Artificial links, called centroid connectors, connect zone centroids to the model network. Neither zone centroids or centroid connectors are present in CAD maps; therefore, they must be created independently. Such a requirement introduces additional human error to the planning process. Ideally, a GIS procedure which microscopically analyzes the spatial and demographic makeup of each zone would be developed to place one centroid within each zone and aggregate the local street network (which is not modeled) into the appropriate number of centroid connectors, joining the centroid to the network.

William Barrett of the Minnesota Department of Transportation has developed procedures using Intergraph's MicroStation and MGE, digitized maps, EDG and UCM programs, and manual procedures to create a regional transportation model [Barrett, 1991]. Others have also developed "linkages", but the key to their success is their ability to automatically process pre-existing graphical data. Upon completion of the model, Barrett identified two primary system weaknesses: complexity and cost within the DOT [Barrett,1991]. System strengths are: 1) compatibility with cartographic maps allows communication through a cartographic product, 2) introduction of the spatial analysis capabilities of GIS to transportation planning enhances the ability to analyze regional systems, and 3) integration of data from several sources facilitates use of more accurate data, providing better planning information and restoring user confidence [Barrett,1991].

Transportation planning agencies need the capability to develop and/or modify UTMS models quickly, efficiently, and inexpensively. Frequently, modified UTP models are near replicas of the original (baseline) models not requiring the development of an entirely new model. GIS can take advantage of this property and be used to manage and store only the changes. Although network changes and certain trip generation characteristics may be accounted for, the models continue to rely on potentially outdated TAZ deliniations. GIS enables overlaying TAZ boundaries on socioeconomic databases (such as TIGER census blocks, parcel coverages, and zip code areas). Moreover, it has been suggested that transportation analysis

zones can easily be redefined within a GIS. O'Neill considers the process of designing TAZs prior to modeling trip productions or travel demand to be flawed. The results of the four step modeling process may be strongly impacted by slight changes in zonal boundaries [O'Neill,1991].

Assumptions about socio-economic characteristics and trip making change over time. As these relationships change, travel demand changes. The criteria for delineating TAZs seems to suggest that, given these conditions, redefinition of zonal boundaries may be required. Unfortunately, traditional UTMS databases do not readily allow for modification of zones. By combining study area definition with trip generation modeling within a GIS, "optimal" zone configurations may be achieved [O'Neill,1991].

In general, the process of developing an urban planning model is complex, regardless of which GIS and UTMS platforms are used. Capabilities of MGE and other GIS software for TIGER and MapInfo conversions enable accessing and converting existing data for a model. For example, the Des Moines MPO uses MapInfo to manage and display TAZ and landuse information. Through use of the MGE/MapInfo translation utility, this information can also be used in conjunction with trip generation (P/A) modeling and zone delineation. Additionally, GIS topological and polygon processing capabilities such as MGE's Analyst (MGA) are useful for model development. By merging (dissolving boundaries between) areas with similar characteristics, simplified thematic maps can be created from disaggregate data (e.g. jurisdictional boundaries can be drawn from census block data). Different GIS platforms have their strengths and weaknesses. An advantage of MGE is its CAD foundation, MicroStation. Although MicroStation and MDL (the MicroStation programming language) functions can be used to automate model development, however, manual procedures are still required. Further, significant training or access to a consultant is required as the developer must have a working knowledge of the GIS components. In the case of MGE, this may include MGE itself, MicroStation, MDL, Oracle, RIS (Relational Interface System), SQL (Structured Query Language), and manual operations.

Developing a GIS from a UTMS Model

Although UTP models are highly capable computational and analytical tools, their usefulness may be limited by their typical operating environments. Besides providing the capability to efficiently create or modify models, GIS also facilitates conversion of existing UTP networks and associated data to a GIS *project*. Using MGE, Tranplan, and some programs (UCM, SQL, and C) developed by Barrett, the authors have successfully completed such a conversion. Rather cumbersome (not fully automated in its developmental stages) the next tasks for the system will be on smoothing processes, eliminating manual operations, and improving the user interface. Presently, the system provides a suitable test environment for demonstrating the usefulness of a GIS over the original UTMS based system.

A key to developing a GIS from a UTMS model lies in the utilization of existing GIS capabilities. The less original programming required to facilitate the development, the better. As more original code is written and more manual procedures are necessary, the system becomes more complex, making it less applicable and transferable. For the most part, the system need only meet three criteria:

- Link and node records, originating from UTP ASCII files, must be stored in the GIS database.

- Coordinate and from-node/to-node data located in these records should be used to create graphical point and line elements in a CAD design file.
- As graphic elements are created, a linkage between the elements and the records used to create the elements must be established.

GIS functions, such as MGE's Feature/Schema Builder, and SQL scripts can be used to satisfy the first criterion. The second and third criteria are, however, much more difficult to satisfy. MGE's Point Placer may be used to create point feature graphic elements from coordinate data located in the node table. A combination of MDL functions and MGE functions, including MsLink Loader, may be needed to create and link the line elements. Processes required to satisfy the second and third criteria are still being developed by Barrett, Souleyrette, Hans, and others.

Upon successful conversion of UTMS link and node data, additional data may added in the GIS. Turn volumes and zonal production/attraction (P/A) data may be of particular interest. Unlike the node and link records, these records do not require a direct linkage to CAD design files. The turn volumes and P/A tables, which are node based, may be transparently joined to the node table. The graphical interface between node elements and node records may then be utilized to access selected columns of the P/A and turn records. This may be accomplished through use of MGE's Join and View Managers.

Simple and universal capabilities of the GIS database are used in the initial development of a GIS from a UTMS model. Relational database capabilities may be exploited in the development of a more powerful planning GIS. Specifically, these capabilities better facilitate the management of transportation scenarios (models or model variations). Transportation scenarios result from changes in spatial data, attribute data, or a combination of both. To date in this work, only capabilities to modify network attributes (e.g. speed, capacity, and turn prohibitor modifications) and demand data (trip generation data) have been developed. Future tasks would address spatial changes (see High-speed section, below).

Although Tranplan and other UTMS platforms are beginning to incorporate more extensive database capabilities into their systems, many existing platforms, including Tranplan 7.2, do not utilize a database management system (DBMS) to store data pertaining to the transportation network. Data are stored as binary or ASCII flat files. These files may be created by the user, independent of the modeling processes, or generated by one of the several component modeling processes of Tranplan. Each time a model input is modified new data are generated. Essential data, both input and output, representing each scenario must be saved as unique files. Use of a traditional UTMS to manage attribute modifications essentially entails saving a series of data files and recording the relationship among the files. Subtle differences between scenarios may only become apparent after extensive review of input and output files.

Using the capabilities of a GIS, scenarios may be managed much more effectively. Changes in network attributes may be represented by data stored in additional columns in database tables. For example, a link record will typically include information on capacities and volumes. Columns representing the capacities and volumes under different conditions (scenarios) may be added to the table. Using a system of SQL scripts and FORTRAN programs, scenario data can be selected for transfer to and from Tranplan. The number of additional columns to be included in a given database table is a function of the number of attribute columns in that table and the number of scenarios the user would like to manage. These columns should initially be populated with baseline data. Although this will result in redundant data, it will allow less complicated data management. There should be no question about which data are to be used for a given scenario. Further, comparisons of baseline data to scenario data, or between scenarios, may be displayed through the GISs graphics. Similarly, to aid in model calibration, those links experiencing high model volume and ground count volume discrepancies can be identified. GIS query and display capabilities (such as those available in MGA) can be utilized here. Queries may involve attribute as well as spatial relationships.

GIS can serve as a medium to incorporate and display much of the data used to develop the UTP model. Overlays of thematic maps, aerial photographs, and land use will add much more depth to the planning model. Unfortunately, many UTP models were not developed with a high degree of spatial accuracy. The GIS networks created from a UTP model will likely not correctly overlay cartographic and digitized maps. Modification of the planning network to fit more accurate spatial data may be necessary in order to fully exploit the GIS data overlay capability. Some GIS packages have tools useful for this modification (e.g. Conflation).

Other benefits of converting UTMS models into a GIS could be realized in conjunction with routing (e.g. school bus) and allocation (e.g. fire stations) capabilities. GIS displays also facilitates easier, faster identification of model coding errors.

A High-Speed Interactive Loop

The "batch mode" linkages of MGE to Tranplan described in the last two sections are limited primarily to exploiting the data management and graphic output capabilities of GIS. Further, the time required for a single run of the transportation planning model for a medium to large region (about one hour on a fast personal computer) prohibits the interactive viewing of outputs resulting from changes in assumptions and data for multiple scenarios. However, the price/performance (processing speed) ratio of computing continues to increase in computers available to public and private agencies (departments of transportation and public works, planning and engineering consulting firms). Within the next five years, the time required to run planning models may be eliminated as a constraint to multiple (dynamic) analyses.

High-speed computing capabilities (supercomputers or high-end workstations) present several opportunities for transportation planning - opportunities which go beyond being able to run models at high rates of speed. We wish to investigate the usefulness of high-speed, next generation computing to transportation planning. By developing an interactive system, GIS can be used to modify model inputs, call for the model to be executed on a high-speed computer, and display the results. The user interface would be a multi-layer thematic map graphic which improves the users ability not only to modify data and assumptions, but to recognize the implications of changes through overlay of input and output networks. Use of high-speed computing available today provides a window through which the future of desktop transportation planning modeling can be viewed. It is expected that during a one to two hour interactive session, an analyst might perform several alternatives or sensitivity analyses, investigating the outcomes (congestion, delay) resulting from various transportation planning decisions (adding new infrastructure, deploying travel demand management strategies, modifying land-use assumptions) or variations in UTMS inputs.

Once again, data modification and management become issues. Early in the chapter, only attribute data modifications were discussed. However, for the GIS to be truly effective, an analyst must be capable of manipulating spatial data as well. Essentially, attribute data modification requires management of changes in the baseline network. Barrett has demonstrated that spatial data manipulation and management are much more complex [Barrett,1994]. A user may require link and node elements to be added to or deleted from a network. Geographic boundaries, such as land use zones or TAZs may be changed. TAZs may also be added or removed.

Scenario management capabilities must include (see Figure 4.2):

- management of network attribute changes (e.g. increasing the capacity of a roadway)
- network spatial modification (e.g. adding new links)
- spatial aggregation of features affecting demand (e.g. TAZ boundaries)
- demand attribute modifications (e.g. TAZ and landuse data)

Assuming that only three scenarios (baseline, last scenario, and current scenario) are to be stored at any given time, three columns, in addition to the attribute columns discussed earlier, must be added to the appropriate database tables. These columns will serve as a means to indicate which records are to be transferred to the planning model. A SQL script, written for each scenario, will transfer data to and from the planning model. The column representing the baseline data will always be used as a reference to allow purging unneeded records from the database, retaining original data and keeping the database to a manageable size.

The analyst will use a computer program to select which scenario he/she wants to work with. Scenarios may be represented graphically in one of two ways.

- Each scenario may be represented by a unique graphic (CAD, *design)* file, or
- a single graphic file may be used in conjunction with multiple MGA "query sets".

The spatial changes occurring in a scenario can be viewed primarily as a collection of the addition and deletion of links and nodes. These additional links and nodes may or may not have a prior relationship with the network. If a prior relationship exists, as is the case when a link is split, a parent/child relationship may be modeled. The original link may be considered the parent element from which the new elements, or children, are created. This allows for reconstruction of the correct graphic elements for each scenario. Otherwise, the record of the element should be deleted and the new elements created. If a prior relationship does not exist, the graphics are identified by new records and the scenario columns in the database.

When a graphic element is replaced or not needed in a scenario, the corresponding records in the database tables should be "retired", not deleted. Using the MGE function GeoDatabase Locate, an element and its corresponding records can be identified in a design file. The proper notation will be used to inform the appropriate SQL script not to use the record. Several options exist with regard to the handling of a graphic element itself. If only one design file is being used, elements should not be deleted because they may represent a link or node in a different scenario. If multiple design files are being used to manage the scenarios, elements may be deleted, but a database linkage must remain intact. To do this, the element will still be located in the baseline network.

Conclusion

There are many applications of the models and tools that may be developed using GIS and UTMS. Three applications discussed in this chapter are using GIS to develop UTMS models, developing a GIS from a UTMS model, and a high-speed interactive loop for alternatives and sensitivity analyses. Models developed or modified using GIS can be used to identify and assess transportation impacts in medium to large urban and suburban regions/areas. New types of analyses facilitated by developing GIS from UTMS models may include spatial overlay of origin-destination information on socioeconomic and demographic data. Alternatives

analyses may be used to support development and investment policy decisions relating to and benefiting say, elderly and disabled populations or economically disadvantaged areas. When developed, such tools can enhance the ability to provide for equitable and efficient allocation of resources, i.e. GIS can effectively compute and display derived data on cost per lane mile or jurisdiction, spatial distribution of benefits, etc.

One GIS package, MGE, has been shown to be useful in the development of a UTMS model based on the Tranplan software. Others have linked or are working on linking Arc/Info, Transcad, Minutp, TModel and other GISs or UTMS packages. While promising and powerful, the linked systems are presently difficult to develop. As predicted by Lewis, there is an ongoing convergence between GISs and UTMS modeling packages [Lewis,1990]. Several UTPSs are developing GIS-type data management and display capabilities while some GISs are developing network modeling modules. For now, MPOs and others interested in one of the three applications described in this chapter will need to work with consultants or expect to develop in house skills well beyond current capabilities.

CHAPTER 5. CLOSURE

General Conclusions

The system developed in this project is an interactive tool which utilizes GIS and graphic user interfaces to change planning model inputs as well as display the results of model runs. This type of system provides an environment for transportation modeling which is superior to older, non-graphic methods which are primarily driven by batch files created in a batch mode. Planners and engineers can more easily visualize data inputs (e.g. socioeconomic variables) using GIS color graphic displays. Outputs, such as traffic volumes on each link are similarly presented. Collections of data used to support a particular model scenario can also be more efficiently stored in a GIS than in a tabular environment. In addition, the interactive nature of the Transportation Planning GIS (TPGIS) permits an analyst to perform what-if scenarios in response to requests by decision makers while they wait.

The TPGIS provides an analyst with the ability to modify data and assumptions and to recognize the implications of changes. Although the system as developed uses a combination of advanced hardware and sophisticated software, technology is becoming available to many planning organizations to allow similar capabilities (desktop mapping and high-speed yet affordable personal computers).

Recommendations

The Intermodal Surface Transportation Efficiency Act of 1991 and Clean Air Act Amendments of 1990 have greatly increased the need for analytical tools applicable to urban and regional transportation planning. Areas of concern include congestion management, air quality analysis, travel demand management, economic development and equity issues. Planners, analysts, and decision makers alike are faced with the need to better understand the impact of policies, plans and growth on transportation networks and populated regions.

The TPGIS procedures developed in this project may be extended and converted into a production environment suitable for most planning agencies. A future effort may develop an accessible version of the TPGIS which may be used for investigating the outcomes of alternative decisions and understanding the sensitivity of forecasts to network supply and demand assumptions and quality of data. **<u>Standard hardware and software</u>** available to State Departments of Transportations, Metropolitan Planning Organizations (MPOs), and Regional Planning Affiliations (RPAs) should be used in such an effort.

REFERENCES

Barrett, William. 1991. Building a Regional Transportation Model with GIS Software. *Proceedings for the 1991 GIS for Transportation Symposium*. Ed. D. David Moyer and Barry L. Larson. AASHTO. Washington, D.C.:117-125.

Barrett, William. 1994. Managing Transportation Planning Networks in a GIS-T Environment. *Proceedings for the 1994 GIS for Transportation Symposium*. Ed. D. David Moyer and Tom Ries. AASHTO. Washington, D.C.:190-194.

Blewett, C.J. and M.R. Lewis. 1991. Method for Using Geographic Information Systems in Travel Demand Modeling and Other Transportation Planning Applications. *Proceedings of the Twenty-eighth Paving and Transportation Conference*.

Choi, Keechoo. 1993. The Implementation of an Integrated Transportation Planning Model with GIS and Expert Systems for Interactive Transportation Planning. Dissertation (Ph. D). University of Illinois at Urbana-Champaign.

Fleet, Christopher R. and DeCorla-Souza, Patrick. 1992. VMT for Air Quality Purposes. *Transportation Planning and Air Quality*. Ed. Roger L. Wayson. American Society of Civil Engineers: New York, pp. 127-141.

Fletcher, D. 1987. Modeling GIS Transportation Networks. *URISA 24th Annual Conference Proceedings*. Fort Lauderdale, Florida.

Gallimore, W. Paul, David T. Hartgen, and Yuanjun Li. 1992. Applications of GIS-Transportation Analysis Packages in Super-Regional Transportation Modeling. *Transportation Research Record*. No. 1364.

Garrison, William L. and Souleyrette, Reginald R. 1990. Relations Between Transportation and Production. *Transportation Research Record*. No. 1262, pp. 21-30.

GIS World, Inc. 1994. *1994 International GIS Sourcebook*. Fort Collins, CO:4-28.

Grubler, Arnulf. 1990. *The Rise and Fall of Infrastructure: Dynamics of Evolution and Technological Change in Transport*. Physica-Verlag: Heidelberg.

Hartgen, David T. 1992. *Super-Regional Very Long Range Transportation Modeling with a GIS*. Center for Interdisciplinary Transportation Studies, UNC Charlotte. Charlotte, NC.

Intergraph Corporation. November 1988. *ORACLE SQL Language Reference Manual*. Dwight Cheu. Oracle Corporation. Huntsville, Alabama.

Intergraph Corporation and Bentley Systems, Inc. 1991. *MicroStation Reference Guide*. Intergraph Corporation. Huntsville, Alabama.

Intergraph Corporation. April 1993. *MGE Analyst (MGA) Reference Manual.* Intergraph Corporation. Huntsville, Alabama.

Intergraph Corporation. April 1993. *MGE Basic Administrator (MGAD) Reference Manual*. Intergraph Corporation. Huntsville, Alabama.

Intergraph Corporation. April 1993. *MGE Basic Nucleus (MGNUC) Reference Manual, Volume 1*.

Intermodal Surface Transportation Efficiency Act of 1991 (Public Law 102-240). 18 December 1991. Washington D.C., pp. 1960, 1963.

Journey-To-Work Trends in the United States and its Major Metropolitan Areas, 1960-1990. (USDOT 1993) USDOT, FHWA: Washington, D.C., November.

Karakatsanis, S.P. 1989. Developing Transportation Networks Using Area Master Files and Autocad. *Annual Conference Proceedings: Roads and Transportation Association of Canada*. Vol. 3.

Kriger, David, Mike Hossak, and Mike Schlosser. 1991. Integration of GIS with the Transportation Demand Model TModel 2 at Saskatchewan Department of Highways and Transportation. *Proceedings for the 1991 GIS for Transportation Symposium*. Ed. D. David Moyer and Barry L. Larson. AASHTO. Washington, D.C.:127-138.

Lave, Charles A. November 1990. Things Won't Get A Lot Worse: The Future of U.S. Traffic Congestion. *ITS Review*.

Lave, Charles A. Fall 1992. Cars and Demographics. *Access*.

Lewis, Simon. March 1990. Use of Geographical Information Systems in Transportation Modeling. *ITE Journal*: 34-38.

McAdams, Michael A. 1992. *A Geographic Information System Application to Regional Subarea Transportation Modeling*. Center for Interdisciplinary Transportation Studies, UNC Charlotte. Charlotte, NC.

Nakicenovic, Nebojsa. 1988. Dynamics and Replacement of U.S. Transport Infrastructures. *Cities and Their Vital Systems: Infrastructure Past, Present, and Future*. Eds. Jesse H. Ausubel and Robert Herman. National Academy Press: Washington, D.C.

National Transportation Statistics, Annual Report. (BTS 1993). United States Department of Transportation, Bureau of Transportation Statistics (BTS), September.

Niemeier, Debbie A. and Beard, M. Kate. 1993. GIS and Transportation Planning: A Case Study. *Computers, Environment, and Urban Systems*. Vol. 17, pp. 31-43.

Nyerges, Timothy L and James D. Orrell III. 1992. *A Geographic Information Systems for Regional Transportation Planning in a Growth Management Context*. Washington State Department of Transportation. Olympia, Washington.

O'Neill, Wende A. 1991. Developing Optimal Transportation Analysis Zones Using GIS. *Proceedings for the 1991 GIS for Transportation Symposium*. Ed. D. David Moyer and Barry L. Larson. AASHTO. Washington, D.C.:107-115.

Rao, Kant, et al. 1992. Evolution or Revolution in Federal Toll Highway Policies? Issues and State Views for the 1990s. *Journal of Transportation Research Forum*. Vol. XXXII.

Replogle, Michael A. 1989. Integration of a Geographic Information System with Computer Transportation Models for Land Use and Transportation Planning. *Second Conference on Application of Transportation Planning Methods*. Orlando, Florida.

Shaw, Shih-Lung. 1993. GIS for Urban Travel Demand Analysis: Requirements and Alternatives. *Computers, Environment, and Urban Systems*. Vol. 17, pp. 15-29.

Simkowitz, Howard J. 1989. Geographic Information Systems: An Important Technology for Transportation Planning and Operations. *Transportation Research Record*. No. 1236.

Southworth, Frank. *VMT Forecasting for National Highway Planning: A Review of Existing Approaches*. Oak Ridge National Laboratory: Oak Ridge, TN.

Special Report 234, Data for Decisions: Requirements for National Transportation Policy Making. 1992. Transportation Research Board/National Research Council: Washington, D.C., pp. 50-51.

Shrouds, James M. 1992. Transportation Planning Requirements of the Federal Clean Air Act Amendments (CAAAs) of 1990: A Highway Perspective. *Transportation Planning and Air Quality*. Ed. Roger L. Wayson. American Society of Civil Engineers: New York, pp. 14-29.

Traffic Congestion: Trends, Measures, and Effects. (USGAO 1989) U.S. General Accounting Office: Washington, D.C., November.

Transportation Research Board. 1993. Adaptation of Geographic Information Systems for Transportation. *National Cooperative Highway Research Program 359.* Washington, D.C.

U.S. Department of Commerce, Bureau of the Census. (Census Bureau, 1975) *Historical Statistics of the United States, Colonial Times to 1970. Bicentennial Edition*. Washington, D.C.: United States Government Printing Office.

U.S. Department of Commerce, Bureau of the Census. (Census Bureau, 1971-93) *Statistical Abstract of the United States*. Various Editions, 1971-1993. Washington, D.C.: United States Government Printing Office.

U.S. Department of Transportation, Federal Highway Administration. (FHWA, 1967-93) *Highway Statistics*. Various Editions, 1967-93. Washington, D. C.: United States Government Printing Office.

U.S. Department of Transportation, Federal Highway Administration. (FHWA, 1987) *Highway Statistics Summary to 1985.* Washington, D. C.: United States Government Printing Office.

U.S. Department of Transportation, Federal Highway Administration. (FHWA, 1992) *Nationwide Personal Transportation Survey: Summary of Travel Trends.* Washington, D. C.: FHWA-PL-92-027.

The Urban Analysis Group. 1993. *TRANPLAN User Manual 7.2*. The Urban Analysis Group. Danville, California.

APPENDIX A

Platform Selection

Availability of hardware, software, and data sets for local transportation networks was the primary factor influencing the hardware and software platform selection for the interface. Intergraph Corporation's Modular GIS Environment (MGE), one of the most popular GIS packages, was chosen as the GIS platform for the prototype interface.[1] MGE itself does not provide spatial analysis capabilities [Intergraph (MGNUC),1993]. Another MGE product, MGE Analyst (MGA), is used for spatial analysis. MGE and MicroStation (Intergraph's CAD platform) are currently used by many agencies, including the Iowa Department of Transportation (DOT).[2] The Iowa DOT, a sponsor of this research, is also interested in an assessment of MGE's capabilities related to transportation planning. Use of MGE facilitates transfer of the interface and application to the Iowa DOT. MGE is capable of interacting with a variety of relational databases through the Intergraph product, RIS. For this application, the ORACLE relational database is used.

Tranplan was chosen as the urban transportation modeling system (UTMS) platform because of its widespread use and analytical capabilities.[3] The Iowa DOT and five of the seven Iowa MPOs currently use Tranplan, making calibrated transportation networks readily accessible. The widespread use of Tranplan also provides a market for future technology transfer.

System Description: Tranplan

The Urban Analysis Group describes Tranplan as a "comprehensive suite of transportation planning computer programs encompassing forecasting capabilities of for both highway and transit systems." Tranplan's suite of programs consists of more than forty modules (or functions). This modular structure facilitates implementation of various transportation planning methodologies. In general, Tranplan possessed the capabilities necessary to perform the four basic stages of transportation forecasting models (i.e. trip generation, trip distribution, mode choice, and assignment).

Tranplan operates as a "batch" system. User created control files, in ASCII format, instruct Tranplan which functions to execute. Control files provide Tranplan with four essential pieces of information: names of the Tranplan functions to be executed; input/output file names and types; options and parameters; and, if applicable, input data (in ASCII or binary format). Input data may be zonal land use data and trip generation rates, friction factors, and highway and/or transit networks [UAG,1993].

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[1] The most popular packages, ESRI's Arc/Info, Intergraph's MGE, and MapInfo are used by over 250,000 persons and comprise more than 60% of the market [Intergraph (MGAD),1993].

[2] The Iowa DOT is currently in the process of selecting a department-wide GIS platform.

[3] Tranplan is one of the top three UTMS models. MINUTP, QRSII (the other top models), along with Tranplan comprise 74 percent of the UTMS model market [Hartgen,1992]. Tranplan currently has more than 500 licenses.

System Description: Intergraph

Intergraph Corporation describes MGE (Modular GIS Environment System) as a "computerized database management system for capturing, storing, retrieving, analyzing, and displaying spatial data." The MGE system is built on seven software products: MGE Basic Nucleus (MGNUC), MGE Basic Administrator (MGAD), MGE Base Mapper (MGMAP), UNIX, MicroStation 32, a relational database (RDB), and a relational interface system (RIS). Three of these products, MGNUC, MGAD, and MGMAP, are MGE component products. MGNUC is the basis for all MGE software products and provides basic functions for project management, data query and review, and use of projection coordinate systems. The system and database management tools essential in project preparation are contained within MGAD. MGMAP modules facilitate most data processing needs, such as data capturing, cleaning, and manipulating. These three products, however, do not provide spatial analysis capabilities [Intergraph (MGNUC),1993]. Spatial analysis capabilities are included within another MGE software product, MGE Analyst (MGA) [Intergraph (MGA),1993].

The spatial data to be analyzed using MGA is created and/or resides in MicroStation format. MicroStation 32 has the capability of creating complete two dimensional and three dimensional graphics which fosters the creation of vector geometry [Intergraph (MGNUC),1993].

Descriptive attribute information, associated with MicroStation graphics, is stored in a relational database systems. Relational database systems (e.g. INFORMIX, INGRES, ORACLE, and DB2) are computer-based record-keeping systems designed to perform data management tasks [Intergraph (MGNUC),1993]. ORACLE, the RDB utilized for the prototype interface, is structured in the form of tables. A table consists of columns and rows. Rows store the data in the table, each representing one occurrence of an entity. A single attribute of an entity is represented by a column. ORACLE indexes provide quick access to rows in a table and enforce the uniqueness of rows within a table. In addition to tables, ORACLE may also contain views, which are logical representations of a table or combination of tables.

Files called tablespaces store tables/views within the ORACLE database. The ORACLE database contains at least one tablespace known as the SYSTEM tablespace. All tablespaces, other than the SYSTEM tablespace, are created by the ORACLE system administrator. The ORACLE system administrator also creates ORACLE users. Only users created by the system administrator are authorized to use ORACLE. However, the Intergraph system administrator must first provide these users access to the Intergraph system. Individual ORACLE users may create tables/views and grant other ORACLE users certain privileges (or operating rights) on their tables/views [Intergraph,1988].

ORACLE interacts with MGE through the Intergraph product, RIS. RIS partitions the ORACLE database into one or more schemas, treating each schema like an individual database. A schema is defined by ANSI SQL Standard as being a collection of tables/views. In RIS a schema is a collection of tables/views owned by an ORACLE user. One schema must be associated with each project on the system [Intergraph (MGNUC),1993].

MGE organizes all the data corresponding to a CLIX directory as a project. Directories containing data, system setup files, output files, other support files, and a schema are located in a project [Intergraph (MGNUC),1993].