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Transportation Research Record 1499

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Foreword

This volume focuses on statewide and metropolitan transportation planning, management systems, and land use–transportation issues.

The papers on statewide and metropolitan transportation planning concern an interactive planning modeling process (Wyoming), an area transportation partnership to assist in the development of the state transportation improvement program (Minnesota), the development of a customer perspective in the statewide transportation planning process (Colorado), a pilot transportation plan for an Indian reservation in western North Carolina, and a community-based, strategic, comprehensive planning process (Ithaca, New York).

The papers that concern management systems fall into two categories: two papers discuss congestion management (data requirements and comparisons and the congestion management program in Ventura County, California); the remaining papers discuss management systems for transport infrastructure.

Three papers discuss transportation–land use issues: transportation planning and hazard mitigation (North Carolina coast), parking restrictions in employment centers and implications for public transport and land use, and transportation sketch planning with land use inputs.

Interactive Statewide Transportation Planning Modeling Process

JIANGYAN WANG AND EUGENE M. WILSON

The Wyoming Multimodal Statewide Transportation Planning (WMSTP) model study was initiated to develop a user-friendly and data-efficient planning process to fulfill Wyoming's statewide planning needs. Described is a cooperative process developed by the University of Wyoming and the Wyoming Department of Transportation. Traditional four-step urban transportation planning models have been used extensively in statewide transportation planning (STP) processes. The Wyoming STP modeling process considers the unique nature of STP processes and travel characteristics in Wyoming. Trip purposes were redefined to fit STP needs. The WMSTP model is a planner-computer interactive process. The process uses traffic count and socioeconomic data as the primary inputs, in addition to the knowledge of the planner. Windows-based computer software packages including Excel, Visual Basic 3.0, and QRS II were used in developing the interactive planning model. To date, the model framework has been established, and the model building and sensitivity analysis have been undertaken.

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) requires each state to develop a multimodal statewide transportation plan. The University of Wyoming and the Wyoming Department of Transportation (WYDOT) began the development of the Wyoming Multimodal Statewide Transportation Planning (WMSTP) model in December 1992. This cooperative effort focused on developing a user-friendly, data-efficient state transportation planning (STP) modeling process.

This paper begins with a discussion of the project team organization, and is followed by a brief outline of the model framework. The focus of this paper is the planner-computer interactive process. Travel segmentation by trip purpose using traffic count data and the origin-destination matrix estimation model with traffic counts and their applications are discussed.

STUDY PROCESS AND PROJECT ORGANIZATION

The ultimate goal of this research is to develop a modeling process that will fit Wyoming's statewide planning needs and be a useful tool for statewide planners. A two-phase study approach was used. Phase 1 focused on a national STP modeling method survey and Wyoming's planning needs investigations. Phase 2 focused on model development using a five-county test area in the southeast corner of Wyoming. The researchers from the university and the planners in WYDOT worked closely through the study process. A planning focus group including personnel from the university, FHWA, and WYDOT provided input into the modeling process and its evaluation.

By the end of October 1994, the framework for a computerized interactive demand model had been established; the travel segmentation by trip purpose model had been completed and applied to the test area (*1,2*). An origin-destination (O-D) matrix estimation process using traffic counts had also been programmed and tested (*3*). The sensitivity analysis for the segmentation model was also conducted to verify the validity of the proposed process (*2*).

The historical review of the nationwide STP activities and methods showed that STP modeling methods have become more simplified and practical. Modeling methods varied from state to state. Applications of microcomputer software have tremendously increased planning staffs' working efficiency. ISTEA requirements and the characteristics and needs of each state were the determinant factors in current modeling approach selection. Wyoming researchers and planners agreed that the WMSTP model should use the ideas and the approaches of other states while carefully considering Wyoming's planning needs (*4–7*).

FEATURES OF THE WYOMING MODEL

The findings concerning the multimodal transportation network and travel characteristics in Wyoming indicated that the influence of through traffic and tourism-oriented traffic should be adequately reflected in the WMSTP model. Because different types of road users have different travel service needs and mode preferences, they were modeled separately. Stratifying total volumes into several major groups by travel characteristics, such as trip purpose and origin and destination, helped to identify the travel behavior and travel pattern of each group of users. In addition to the roadway travel analysis, parallel efforts considering rail, air, and public transit in a statewide context are being undertaken. After the analysis on each mode is completed, the next step is to examine the intermodal implications for Wyoming. Origins, destinations, types of travel, and product types become key intermodal parameters. For example, 92 percent of the freight transported on railroads that originates or terminates in Wyoming is coal (*7*). Other bulk chemical raw materials are most of the remaining rail goods. These types of products are not generally suited for transport by other modes.

STRUCTURE OF THE WYOMING MODEL

The Wyoming modeling system begins with a travel characteristics analysis (see Figure 1). The outputs from these models are segmented traffic counts by trip purpose and trip origin-destination matrices. Based on the knowledge obtained from these analyses, the demand changes are estimated for land use or transportation system changes. The estimated trip tables for each trip purpose are the input for mode split models and trip assignment models. The segmented traffic flows formed a solid foundation for intermodal analysis.

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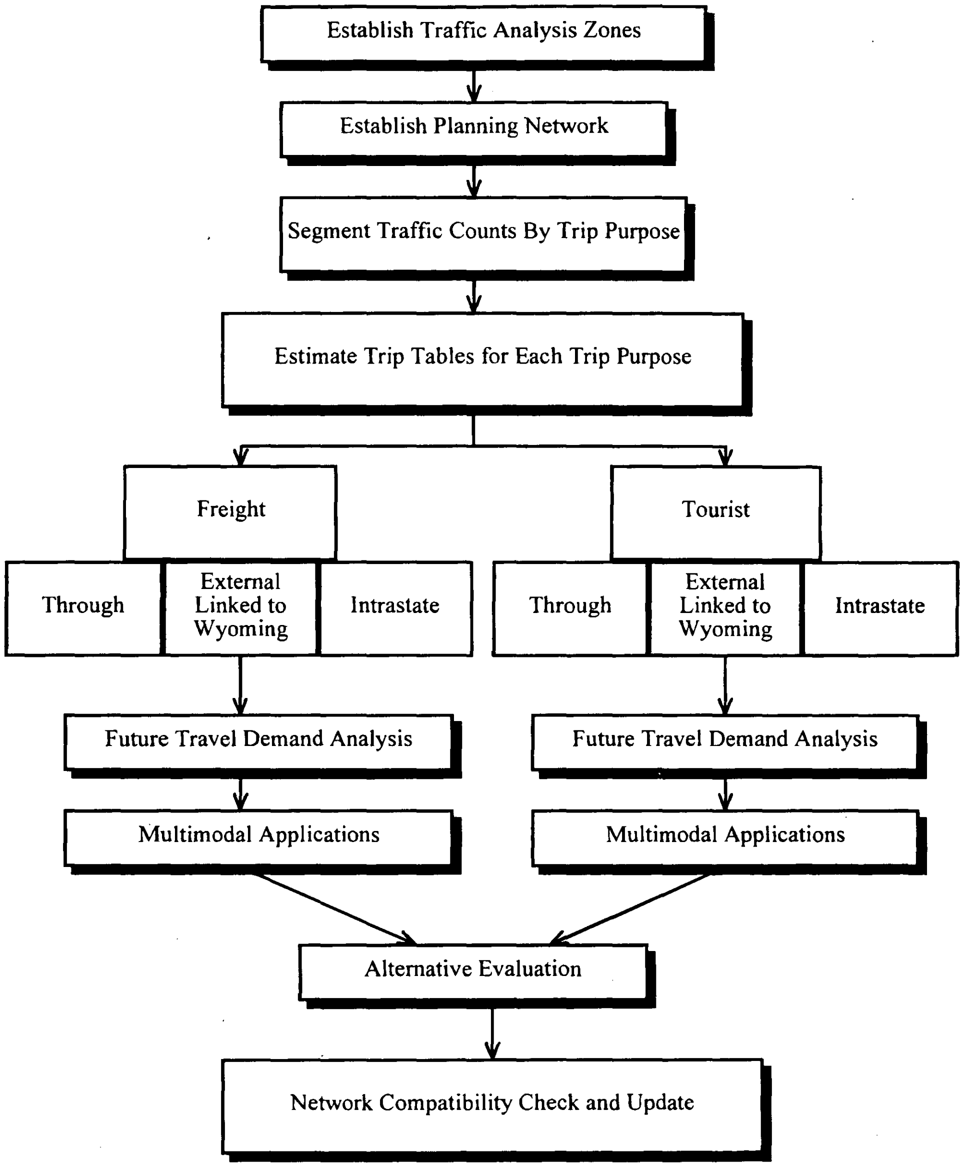

FIGURE 1 Wyoming STP model framework.

In developing the model framework, differences between urban transportation planning and STP were recognized. In urban transportation planning, a large number of trip purposes are generally used to segment the urban travel market. Proposed here is a more generalized and simpler definition, which is adaptable to Wyoming's rural travel. Trip purposes used were *goods movement*, and people movement stratified by *work (commuter)* and *tourist (noncommuter)* travel. Work trips reflect regularly scheduled commuting trips between cities. Tourist or all other people trips reflect the irregular (unscheduled) travel that occurs between cities. These trips include business trips, social and recreational trips, and shopping trips that are taken by Wyoming residents or nonresidents. As the procedure was refined, the need to segregate passenger travel into two distinct purposes was evaluated. Work commuting between cities does not constitute a high percentage of intercity traffic, except for few locations in the state due to the spatial separation between cities.

After analyzing the traffic temporal distribution patterns, it was recognized that traffic flows peak on a July weekend for most Wyoming roadway links. Tourism-oriented traffic is significant in Wyoming. Freight traffic volumes are also higher during summer months. A typical temporal traffic pattern is shown in Figure 2. The July weekend peak traffic volumes illustrated are typical for both truck and passenger travel. Since few weekend traffic volumes are commuter related, goods movements and tourism travel are the trip purposes of primary concern.

PLANNER-COMPUTER INTERACTIVE MODELING PROCESS

The user interfaces in this interactive modeling process allow the planner to influence modeling by communicating with the program. New modeling methods, such as O-D estimation with traffic counts

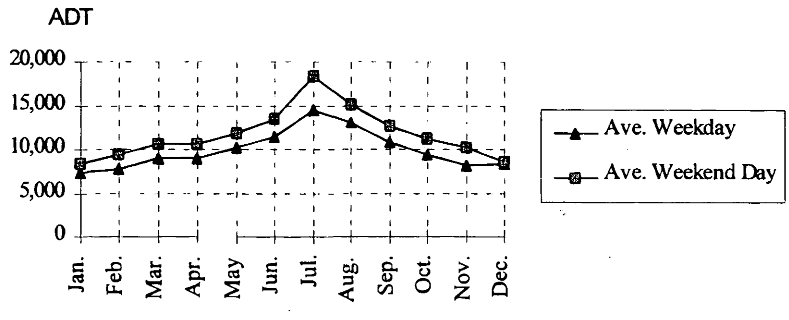

FIGURE 2 Typical monthly traffic volume trend—I-25 in 1992.

and travel segmentation with traffic counts, are used to reduce input data needs. Traffic count and socioeconomic data are the primary input sources. The judgment and the knowledge of the planner are complementary inputs.

The WMSTP modeling program uses three Windows-based computer software packages and integrates them into a menu-driven program. Visual Basic serves as the program organizer. From the main menu, built with Visual Basic, all model programs written with Excel, Visual, and QRS II can be activated. These programs include travel segmentation by trip purpose (programmed with an Excel Macro, which is written by Visual Basic for Applications), O-D estimation models (programmed with Visual Basic and QRS II), and demand analysis models (programmed with Visual Basic and QRS II).

The software was selected for programming and maintenance convenience as well as analysis capability. Visual Basic and Excel Macro are relatively easy to program and provide adequate user interface functions. The input data files to QRS II are generated from the Visual Basic program and the Excel Macro. Excel performs data processing, charting, and the interactive travel segmentation process. The interactive travel segmentation process and the O-D estimation model are discussed in the following two sections.

Interactive Travel Segmentation Process

The normal method for accomplishing traffic split by trip purpose is to conduct extensive household surveys and roadside interviews. However, both approaches are costly in terms of manpower and time required. The proposed approach uses existing traffic count data and the planner's judgment as inputs (*2*). The interactive program developed performs the following actions:

- Processes several types of raw traffic count data automatically to generate tables and traffic pattern charts;
- Checks data availability for each study location and verifies data validity;
- Obtains user's input by allowing the user to choose the data type to be used in the process, select the action taken for the next step, and provide model factors to the process; and
- Stratifies link traffic volume by trip purpose and generates output tables, charts, and data files required by the O-D estimation models and QRS II models.

The basic concept of the proposed methodology is practicality. For roadways, private vehicles are used as the major passenger transportation mode, and freight is transported by trucks. Certain classified and nonclassified traffic counts are regularly collected. Trips made by road users for different trip purposes are characterized by a specific temporal distribution pattern. Based on this knowledge, reasonable assumptions about the temporal distribution for each trip purpose are made. Combining assumptions and available traffic count data, the approximate traffic volumes by major trip purposes are estimated. Related land use data may also be collected as a complementary data source to help understand the traffic variation patterns and make assumptions. The segmentation results are verified or improved through the demand-modeling process.

The primary objective of the travel segmentation process was to obtain July weekend truck and passenger vehicle traffic flows. The process developed stratifies link traffic volumes into (a) monthly average weekday passengers cars, (b) monthly average weekday trucks, (c) monthly average weekend daily passenger cars, and (d) monthly average weekend daily trucks. Using available input traffic count data, the segmented traffic flows are tabulated and charted for the user to view and use in the later modeling process.

The flow chart of the interactive segmentation process is shown in Figure 3. Based on the examination of existing traffic counting programs, three types of traffic counts were found valuable to the segmentation process: automatic traffic record (ATR) reports, port of entry (POE) truck counts, and vehicle miles book (VMB) data. If automatic vehicle classifier (AVC) counts are available at a location, they can be used instead of ATR and POE count data. Count data availability varies by roadway link. If all three types of count data are available for the link, the standard segmentation procedure can be carried out automatically by the program. When one or more types of data are missing at a location, more user involvement in the process is required. The user interface will help the user choose the proper complementary data type. When continuous counts are unavailable at certain locations, short-term counts at the same location or substitution of same-type counts at a nearby location may be used. All regularly available traffic counts, such as traffic control counts (2-week nonclassified counts), coverage counts (24-hour nonclassified counts), and 24-hour manual classification counts can be processed and charted with the program. A traffic pattern chart (similar to Figure 2) for any nearby ATR station can be generated. After review, the user is asked to decide which data source to use as a complementary source for the missing continu-

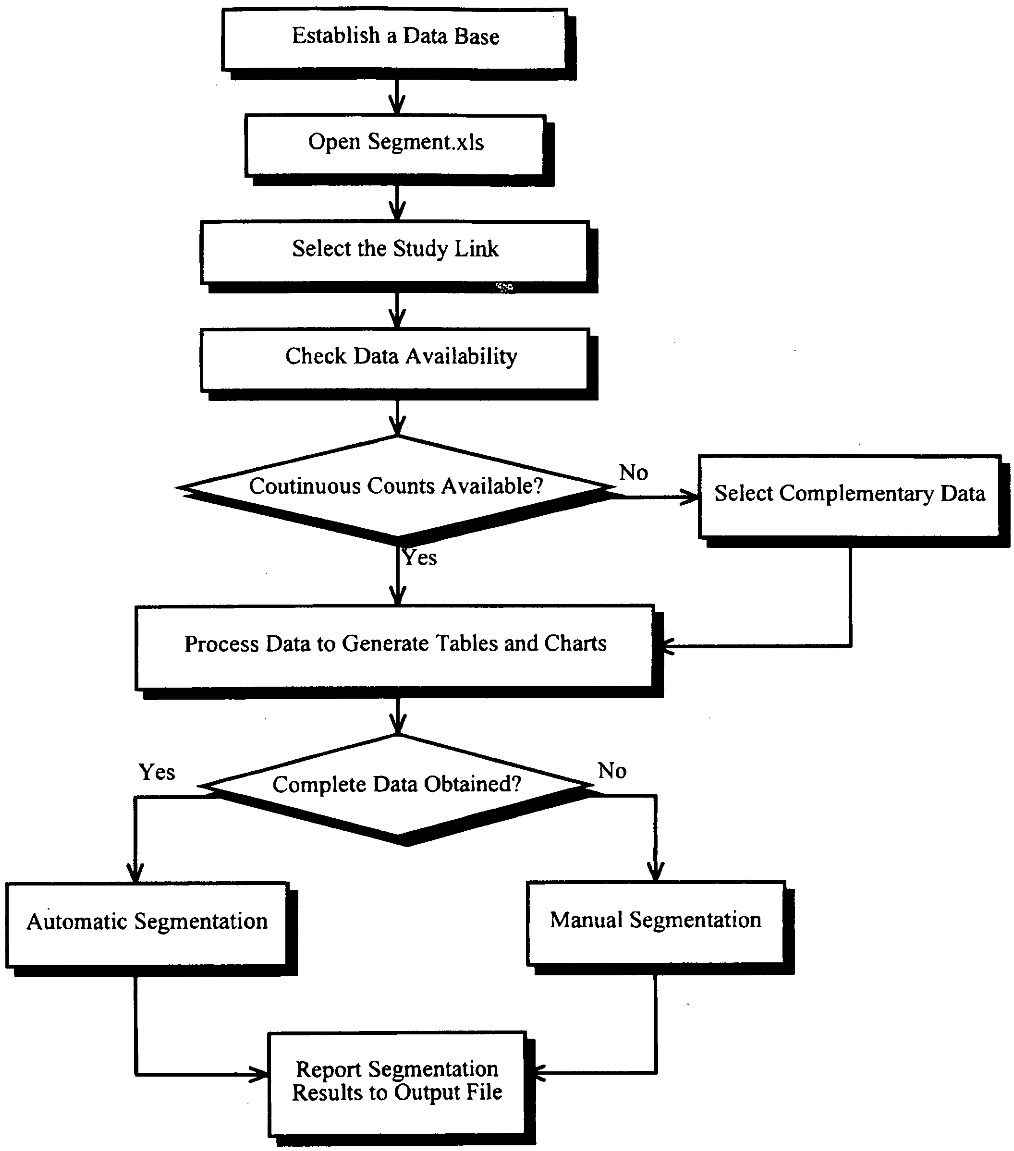

FIGURE 3 Travel segmentation process.

ous counts. Dialogue boxes and user menus are used to build user interfaces.

To assist, a data base is designed for the user to enter the link name, link location, ATR location, and file names for all available count data. An Excel spreadsheet is used. Every row is a record for a roadway link, and each column is a data field. The data base can be either edited manually using the Excel spreadsheet function or edited from the segmentation program interactively. The input data files required by the program are organized and made available through this data base. In addition to data-processing functions, the segmentation process based on entered traffic counts is automated in an Excel Macro subroutine. The segmentation results are then tabulated and charted automatically.

Sensitivity Analysis

Sensitivity analysis is used to evaluate the corresponding output error level when the input data of a modeling process deviate from their true values by a certain magnitude. For instance, in a travel segmentation process, when a 5 percent error occurs in the input ATR count data for the study link, sensitivity analysis provides the error level (i.e., 10 percent) on every resulting classified traffic volume, such as monthly average weekend daily trucks. Sensitivity analysis is critical to verify the validity of all interactive modeling processes. If this analysis detects a larger output error level than the tolerance allowed by the STP planning process (i.e., 15 percent), extra data collection efforts are recommended for the location. The sensitivity analysis for the travel segmentation process is discussed briefly in the following paragraphs as an example.

In the travel segmentation process, a set of equations was established based on the relation between each type of output and input data. The following sample equation calculates the error level on output monthly average weekend daily passenger car volumes when the input monthly average daily truck volumes increases by ΔT_{TI}:

$$\Delta T_{\mathrm{P,SS}} = -\frac{14\Delta T_{TI} R_{\mathrm{SS/M\text{-}F}}}{5 + 2R_{\mathrm{SS/M\text{-}F}}} \qquad (1)$$

where $\Delta T_{P,SS}$ is the error occurred on output monthly average weekend daily traffic (car/day) and $R_{SS/M-F}$ is the ratio of weekend truck traffic to weekday truck traffic.

Sensitivity analysis was conducted for different roadway links with different data availability. These tests demonstrated that, based on the existing traffic counts in Wyoming, the segmentation process generally provides classified peak traffic volume data with adequate accuracy. Under the poorest data availability, the output error level was controlled to under 20 percent. In most cases, the error level on interstate and principal highways did not exceed 10 percent. Higher error levels usually occurred on secondary highways. Due to the significantly lower traffic volumes on secondary highways, the higher error level does not significantly affect the overall modeling accuracy.

Estimation of Origin-Destination Matrices with Expert Survey and Traffic Counts

Estimation of trip matrices for July weekend freight and tourist travel is the next step. These two trip matrices provide the trip distribution for through travel, external travel linked to Wyoming, and intrastate travel. Understanding of this distribution is significant for intermodal analysis.

Traditionally, O-D matrices are estimated by household survey and roadside interviews. Since the 1970s, new O-D estimation models using traffic counts as primary input have been developed (*8–10*). The idea of this new methodology is to obtain the O-D matrix that best replicates the counted link traffic flows. Following is a brief discussion of the procedure.

Consider a study transportation network with n traffic analysis zones. If link traffic volumes (V_a) are available, the following equation is true (*9*):

$$V_a = \sum_i \sum_j p_{ij}^a T_{ij} \qquad (2)$$

where

T_{ij} = the number of trips from i to j;
P_{ij}^a = the proportion of trips from i to j that use link a; and
V_a = the traffic volume on link a.

This is the fundamental equation in the estimation of the O-D trip matrix from traffic counts. This equation describes the relationship between O-D trips and link volumes. In this equation, when link volumes are available and the path choice behavior is assumed known (p_{ij}^a can be calculated by a selected trip assignment model), the number of trips between each O-D pair (T_{ij}) is estimated by solving the equation. Different models have been developed to solve the equation. The entropy maximization (EM) model is one that is extensively used. This model is relatively easy to apply and generally results in an acceptable solution. Solving Equation 2 with the EM model, the elements in O-D trip table are estimated as (*9,10*)

$$T_{ij} = t_{ij} \prod_a X_a^{p_{ij}^a} \qquad (3)$$

where t_{ij} are the trips i to j from a preliminary O-D table and X_a is the trip estimation factor for link a (iterative solution based on Equation 2).

In Equation 3, a preliminary O-D table (t_{ij}) is required. Generally, an old trip table or a table estimated with the gravity model can be used. In the Wyoming study, a small-scale expert survey was conducted to generate preliminary trip tables for both tourist and freight trips. Segmented July weekend link traffic counts were used to provide link volumes (V_a). The process was tested in the southeast area of Wyoming.

The EM modeling and survey data processing procedures were programmed with Visual Basic. QRS II was used to conduct the trip assignment. The proportional use of any link (a) by any trips between any O-D pair (p_{ij}^a) was obtained. A program was developed to read the segmented link traffic counts (V_a) from Excel and enter p_{ij}^a from the QRS II output file. The program allows the user to select the accuracy level of link volume replication and the maximum iteration number. Trip tables for the test area were estimated for the 1992 July weekend traffic. The link volume replication error level was controlled under 3 percent.

For this five-county area, based on the findings from the estimated O-D tables, through traffic is dominant. This is true for both weekend tourist travel and freight movements, but especially for freight. Internal-internal travel was the least frequent travel type. For goods movement, approximately 50 percent of total trips were through the area; 45 percent were internal-external and external-internal trips; and only 5 percent were internal-internal trips (*3*). As the study area is extended to the entire state, the percentage of through traffic will decrease, but the same trend should hold. The bridge state characteristics of Wyoming are a significant factor in planning for Wyoming's future transportation system.

SUMMARY AND CONCLUSIONS

The features of STP modeling in Wyoming have been discussed. Central to the process was to consider travel in Wyoming for a peak weekend in July. This resulted in a two-purpose model for highway travel (goods movements and tourism travel). Since the spatial separation of Wyoming cities is such that work-related travel does not increase weekday summer flows over weekend volumes, this peak weekend approach was used.

Multimodal issues are important only for movements that originate or terminate in Wyoming. Wyoming is considered a bridge state due to the high percentage of travel external to the state. The need, however, is to be able to determine potential shifts as well as analyze future transportation demand for all modes. The major future internal economic growth hinges primarily on tourism and resources development. To plan for statewide transportation, it is important to isolate types of passenger travel and goods movement, and major origins and destinations. Scenarios associated with different land use or transportation alternatives may then be evaluated by isolating the potential changes in demand.

Emanating from this study are the following conclusions:

- A cooperative modeling approach helped ensure that the modeling process will fulfill Wyoming's planning needs.
- The Wyoming STP model uses an interactive modeling process that is data efficient and user friendly. It combines the power of the computer, the use of existing data, and the knowledge and judgment of the planner.
- Classifying existing traffic flows on network links by trip purpose and origin-destination yields a better understanding of Wyoming's travel characteristics. This understanding provides a solid foundation for an intermodal analysis.

ACKNOWLEDGMENTS

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Minnesota's Intermodal Surface Transportation Efficiency Act Area Transportation Partnerships: A Substate, Multicounty Geographic Basis for Making Transportation Investment Decisions

ROBERT LOWE, JR., AND JON A. BLOOM

Some of the actions taken during Minnesota's implementation of the Intermodal Surface Transportation Efficiency Act (ISTEA) are summarized. The focus is on the development of area transportation partnerships (ATPs). The establishment of ATPs was a central tenet in the development of the first state transportation improvement program (STIP). This transportation investment process is but one model for the implementation of ISTEA and the development of a STIP. Minnesota introduced the concept of ATP as a substate, multicounty geographic basis for transportation investment decisions. The partnerships depend on cooperation between all modes and state and local transportation interests. ATPs consist of a combination of local elected officials, local transportation planning representatives, and state transportation officials. These officials work, where possible, through existing organizations, such as the Minnesota Department of Transportation (Mn/DOT) districts, metropolitan planning organizations, and regional development organizations. The boundaries selected for the partnerships are based on the Mn/DOT state-aid districts, which respect county lines. The ATPs are responsible for integrating the priorities for highway and transit capital activities using federal aid for highways into a draft areawide transportation improvement program (ATIP). Draft ATIPs include a prioritized list of projects to aid in solving transportation problems and implementing the long-range objectives for the area. Each ATP is responsible for submitting an ATIP to Mn/DOT. Mn/DOT evaluates each ATIP for consistency, determines the appropriate funding level, and consolidates them into the STIP.

This paper summarizes some of the actions taken during the implementation of the Intermodal Surface Transportation Efficiency Act (ISTEA) in Minnesota. This transportation investment process is one model for the implementation of ISTEA and the development of a state transportation improvement program (STIP). The focus was on the development of the first STIP. The establishment of area transportation partnerships (ATPs) was a central tenet in the development of the STIP.

Within Minnesota, the federal highway aid expended during the 1992 federal fiscal year included funds made available under both the old (pre-1992) federal aid programs and the new ISTEA programs. A conscious decision was made to opt for a modest transition period and continue the old way of doing business during fiscal year 1992. The spending plan developed for 1993 was in many ways a transition into a new way of doing business. The 1993 spending plan was reviewed by the Minnesota Department of Transportation (Mn/DOT) Modal Integration Council (representing all modes). The department's district offices shared the spending plan with constituencies that included the metropolitan planning organizations (MPOs) and regional development organizations (RDOs). This review became part of the transition strategy.

The department chose to involve a broad cross section of transportation professionals, elected officials, special-interest groups, and the public in defining the directions for this new way of doing business. A statewide workshop was convened in May 1992 to create a forum to share information and build understanding among the many groups with interest in transportation issues. The workshop was attended by about 160 individuals with diverse backgrounds. The workshop shared ideas, explored possibilities, and investigated strategies for implementing ISTEA. A strong message throughout these sessions was a desire for local influence in transportation investment decisions.

Many requests, both formal and informal, called for a geographic focus to transportation decisions through public participation. Public response, however, on geographic decision making did not create a consensus on how to do it. Diverse suggestions emerged for implementing ISTEA. A new method for decision making emerged that expanded the role of local entities while maintaining some of the familiar ways of the past. Mn/DOT developed a substate geographic basis for transportation investment decisions. This was consistent with internal consensus on the district role in planning and programming.

AREA TRANSPORTATION PARTNERSHIPS

During 1993, the department began implementing this cooperative regional approach to making transportation investment decisions. Figure 1 displays the partnerships and activities necessary to produce a STIP.

What Are Area Transportation Partnerships?

Creating ATPs within the state provided a regional framework for prioritizing investments in the transportation system. Satisfying regional transportation priorities was the objective across the state. The partnerships foster improved relationships and participation

Minnesota Department of Transportation, MS440, Transportation Building, 395 John Ireland Boulevard, St. Paul, Minn. 55155.

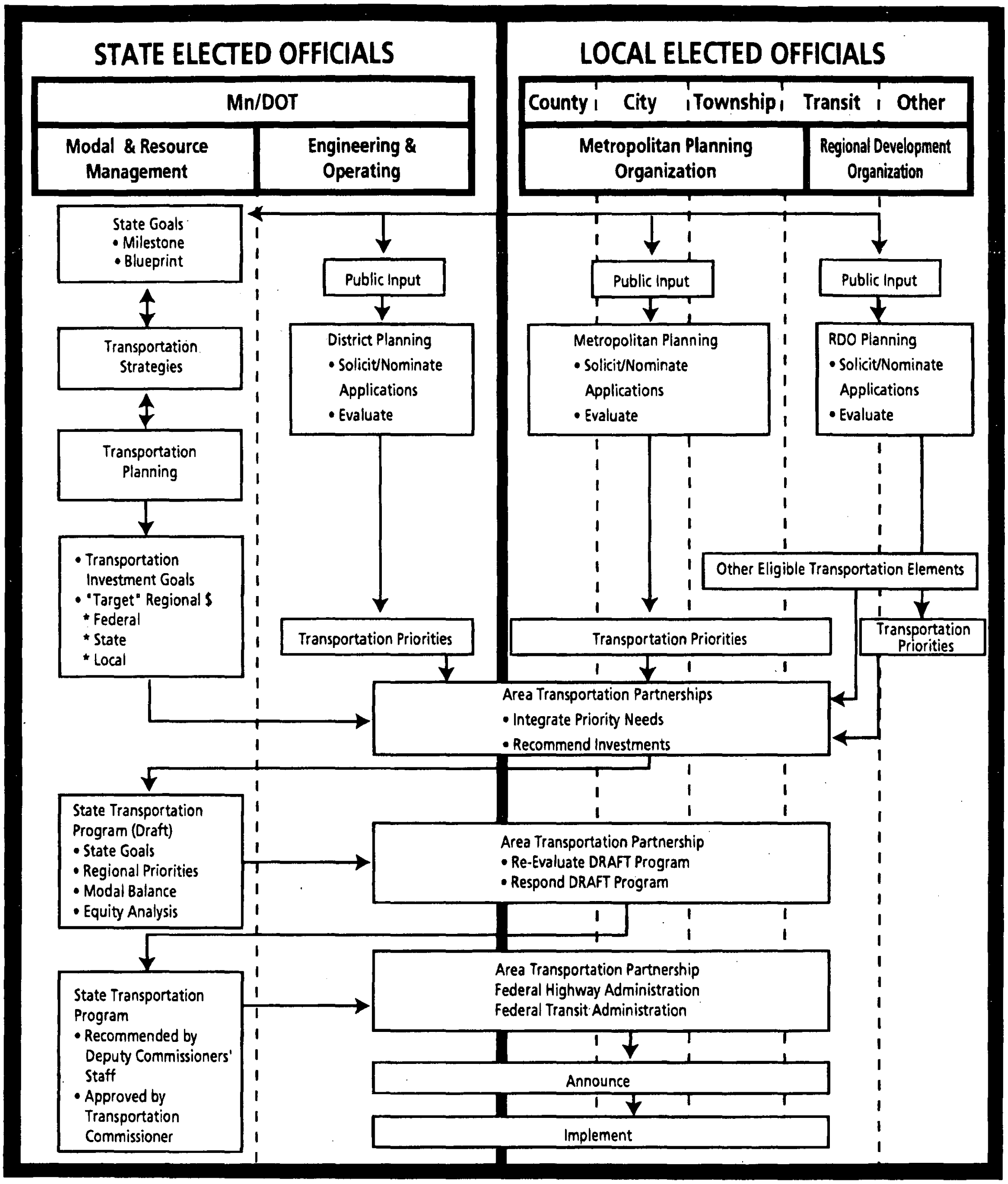

FIGURE 1 Transportation investment process.

between state and local interests. They integrate priority needs for the area and recommend investments and solutions to transportation issues.

The partnerships take their principal form from the guiding tenets of ISTEA—the cooperation between all modes and all state and local transportation interests. Membership consists of a combination of local elected officials, local transportation planning representatives, and state transportation officials. These officials work, where possible, through existing organizations such as Mn/DOT districts, MPOs, and RDOs.

The typical ATP represents a Mn/DOT district, one to three RDOs, an MPO, and special interests. The partnership includes local officials responsible for transit operations in urbanized, small urban, and rural areas. The focus for future years is to include more elected officials and special interests.

The ATP built on the transportation planning structure that was in place or was being implemented in Minnesota. MPOs and RDOs exist in most areas and cooperated in the processes used for making decisions. They represent local government and include local elected officials who are accountable for the decisions. Using existing organizations and planning processes ensures broad-based involvement in transportation decisions.

The ATP boundaries follow county lines. The boundaries selected for the partnerships were based on the Mn/DOT state-aid district boundary. The use of state-aid district boundaries aids the district in the coordination and staffing of the ATPs. Similar arrangements were established where there were no functioning RDOs. Where counties experienced a district-RDO boundary overlap, the affected counties were able to choose a permanent ATP based on the RDO or Mn/DOT district area.

What Are the Duties and Responsibilities of ATPs?

ATPs were critical to implementing ISTEA in Minnesota. The partnerships respond to the request for more local authority and responsibility for transportation decision making. Implementing ISTEA included developing a new integrated process for transportation investment decisions based on prioritizing transportation needs. The process ensures all eligible interest groups access to planning and decision making and fair evaluation of eligible proposals.

The ATP considers the federal transportation investment for transportation-related activities within its geographic boundary. The partnership, in integrating state and local priorities, recommends the areawide investment in transportation activities for all federal highway funds within its area. ATPs recommend a project schedule for all federal highway formula funds, recommend a realistic schedule for federal demonstration projects, and consider requests for allocated federal aid highway funds in developing the regional priorities.

Draft areawide transportation improvement programs (ATIPs) include a prioritized list of projects that aid in solving transportation problems and in implementing the long-range objectives for the area. Developing an ATIP begins with a target funding level based on the ATP's estimated share of state and federal transportation funding. A target funding level is a place to start the process, not the answer to a funding question. Targets are not allocations but are funding estimates used to assist in planning and establishing priorities. The ATP considers all sources of funding—federal, state, state aid, and local—in developing an ATIP.

The transportation investment process is driven by a declaration of statewide goals and objectives and those transportation strategies and directions described in national and state legislation. The statewide investment goals are drawn from statewide planning and policy studies and are to be used as an aid in determining priorities. The principal emphasis of the goals is to preserve and manage existing transportation systems.

Mn/DOT considered draft ATIPs prepared by each ATP for the STIP. The ATIPs were evaluated for consistency with state transportation investment goals. The eight ATIPs were consolidated into a preliminary STIP. Fiscal adjustments are made for regional priorities and statewide balance in developing a draft STIP. The ATPs reviewed and commented on the draft STIP. After considering the ATP comments and recommended adjustments, the STIP was forwarded to the Mn/DOT commissioner for review and approval. The STIP was then forwarded to FHWA and FTA for review and concurrence.

The STIP for 1994–1996 was approved in March 1994 by FHWA and FTA. The STIP was analyzed by Mn/DOT and actions recommended for future STIPs were brought to the attention of the district and ATP.

This procedure ensures that new partners, new programs, small programs, and required spending limit programs are dealt with by the ATPs. A status report on how the ATP process worked was prepared. The analysis alerted ATPs to what funds were in danger of lapsing (possibly requiring more emphasis in future ATIPs), and what needed to be done to keep the ATIP in balance so that the future year(s) would not be constrained by the need to meet required minimum ISTEA spending levels.

EVALUATION OF THE FIRST YEAR

The department conducted four regional ISTEA-ATP workshops in various locations throughout the state in late 1993. The participants of these workshops represented the RDOs, MPOs, local elected city and county officials, Mn/DOT, other state and federal agencies, and local businesses and interested parties. The purpose of these workshops was to discuss a number of issues regarding ATPs and the ISTEA implementation process that were raised during development of the first STIP.

The issues discussed were grouped into four main categories. Each category included several individual subcategories. The four main categories were

- *ATPs*—makeup, membership, role, decision-making process, and boundaries;
- *Targets*—their basis, who develops them, and what funds are included and amounts;
- *Equity*—what is equity in terms of how funding is awarded to the ATP areas and how it is applied; and
- *Special programs*—what the ATP responsibilities are regarding special programs, and how special program needs can compete with the traditional highway programs.

A draft summary of recommended answers and actions was forwarded to the Mn/DOT district offices for review and comment. The comments regarding external issues discussed at the regional workshops and internal issues identified during ISTEA interoffice meetings were used in the development of guidelines and/or procedures for the ATPs and Mn/DOT to follow in developing the 1995–1997 STIP.

CONCLUSION

ISTEA has afforded Mn/DOT the opportunity to continue a movement toward increased and ongoing public involvement in decision making. The state's transportation investment process is a part of the department's emphasis on a strategic management process. The strategic management process integrates transportation planning and programming into the long-term economic future of the state.

The creation of ATPs led to the development of an integrated process for making transportation investment decisions in Minnesota at a regional level. It has encouraged the RDOs and Mn/DOT districts to enhance their transportation planning activities so that in combination with already-established MPO planning processes, they provide for a truly integrated process for developing regional ATIPs. The key factors in developing the process include flexibility, transferability, predictability, and cooperation.

The basic principles guiding the process are the following:

- A statement of statewide goals, objectives, and strategies;
- Comprehensive planning with local, regional, and state involvement;

• Planning for all modes of transportation integrated into the process;
• Multicounty geographic regions as the basis for investment decisions;
• An emphasis on the preservation and management of existing transportation systems;
• Flexible regional funding targets;
• Prioritized areawide transportation investments;
• Fairness, equity, and accessibility; and
• Use of ISTEA management systems to assist in planning and priority decisions.

Mn/DOT will evaluate equity (highway-transit-other, state-local, passenger-freight, rural-urban, intermodal and geographic activities) at the end of each funding period. The equity analysis may be a factor in state investment recommendations. The cycle will be repeated annually until there is enough familiarity to extend it to a 2-year process.

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On Native Ground: Collaborative Transportation Planning on Indian Reservations

BRIAN D. TAYLOR, DAVID R. GODSCHALK, AND MICHAEL A. BERMAN

A pilot transportation plan, applying the new guidance of the Intermodal Surface Transportation Efficiency Act (ISTEA) to a Native American reservation, has been developed. This plan, for the Cherokee Indian Reservation in western North Carolina, was a cooperative venture between the federal government, the state of North Carolina, and the Eastern Band of the Cherokee Indians. Ways to increase tribal control over future transportation planning are recommended. Indian tribes are explicitly intended to benefit under the new, more open transportation planning process established by ISTEA. The study devoted particular attention to the nontechnical, process-oriented phases of transportation planning—much more than in most transportation plans prepared by outside consultants. Given the lack of tribal involvement in planning reported in the literature, it was assumed that such emphasis would be necessary. Despite the focus on process and local participation, efforts met with mixed success. Difficulties in accomplishing standard transportation planning collaboratively with a tribe include past intergovernmental tensions, a tradition of grant-seeking as a substitute for long-range planning, and a lack of tribal commitment to plans prepared by outside consultants. To overcome such factors, more substantial changes to the traditional transportation planning process may be necessary. The recommended approach brings tribal leaders and their concerns more actively into transportation planning. Lacking in-house transportation expertise and commitment to comprehensive planning, a more collaborative approach—combining the traditional, time-tested technical planning process with strategic elements—is suggested. Strategic planning, with its focus on the critical issues perceived by local leaders, is more likely to engage and capture the attention of tribes previously outside the transportation decision process. It is also more likely to generate plans that are understood and supported by tribal leaders.

This paper reports on a pilot transportation plan for the Cherokee Indian Reservation in western North Carolina. A recent change in federal transportation policy mandates increased tribal participation in transportation planning on reservations; the process used to develop this plan was an important first step in that direction. The plan is the result of a unique, cooperative venture between the federal government, the state of North Carolina, and the Eastern Band of the Cherokee Indians. We reflect on this cooperative effort and make recommendations on how tribal participation in transportation planning can be increased on this and other reservations.

In crafting a new federal transportation policy for the 1990s, Congress sought to open the decision-making process to a number of formerly excluded constituencies, including Native Americans. For example, the finance, construction, and maintenance of highways in the United States has historically been a cooperative venture between the FHWA and the state departments of transportation. Most other constituencies—regional governments, counties, cities, citizen groups, environmentalists, Indian tribes, etc.—have traditionally played only secondary roles in shaping highway development. This traditional arrangement—with the federal and state departments of transportation at the center and all others on the periphery—was fundamentally changed with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. Under ISTEA, local governments and interest groups are ceded a larger role in the development of local highway, street, and transportation systems.

Indian tribes are explicitly intended to benefit under the new, more open transportation planning process established by ISTEA. And, in addition to general provisions that provide for increased cooperation, ISTEA also provides specific assistance to Native Americans, in terms of both funding for transportation projects and improved planning. Given the historical lack of tribal participation in transportation planning, our study focuses on the process of developing a transportation plan for the Eastern Band of the Cherokee Indians to make recommendations to improve cooperative federal, state, and tribal transportation planning.

PROCESS AND PRODUCTS: DEVELOPING A TRANSPORTATION PLAN FOR CHEROKEE

This project began with informal discussions between the Eastern Band of the Cherokee Indians (EBCI) planning staff and FHWA staff during 1992 over the need for cooperative federal, state, and tribal transportation planning on the Cherokee Reservation. From the outset, this study had two specific goals:

- To cooperatively develop a plan for the Cherokee Reservation for long-range transportation development, transportation project selection, and promotion of tourism recreational travel; and
- To use this joint planning venture as a model for future cooperative transportation planning efforts on Indian reservations nationwide.

The first of these two goals was met with the completion of the *Cherokee Indian Reservation Transportation Plan* in June 1994 (*1*). A second report—which proposes a model for future cooperative federal, state, and tribal transportation planning—was completed in August 1994 (*2*) and is summarized in this paper.

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Given the focus on cooperative planning, a diverse project team and project advisory committee were assembled. The project was headed by the Technology Transfer Center at the University of North Carolina Institute of Transportation Research and Education (ITRE). ITRE was selected because the Technology Transfer Center specializes in local government outreach and training in transportation engineering. The project team, which was composed entirely of non-Indians, worked with Cherokee tribal planning staff under the guidance of a large and diverse technical advisory committee. This committee, which included both tribe members and nontribe members, initially comprised representatives from the tribal government, tribal transportation, tribal travel and promotion, the Bureau of Indian Affairs (BIA), adjacent county governments, the National Park Service, and the Tennessee Valley Authority. A representative from the EBCI Senior Citizens Program, which operates van service for elderly and disabled tribe members, was later added to the committee.

The preparation of the plan and the bulk of the technical analysis were done by Kimley-Horn and Associates, Inc., a private transportation planning and engineering firm in Cary, North Carolina. The Kimley-Horn staff was assisted in several areas by faculty and students from area universities (see Table 1):

- The Department of City and Regional Planning at the University of North Carolina at Chapel Hill assisted with public participation and needs assessment.
- The Department of Park, Recreation, and Tourism Management at North Carolina State University assisted with tourism forecasts.
- The Departments of History and Anthropology at the University of Tennessee, Knoxville, provided background information on Cherokee culture, politics, and archaeology.

Responsibility for process observation and assessment, including the preparation of this report, was assigned to the team from the Department of City and Regional Planning at Chapel Hill. Its role was not simply to observe and record; it worked actively throughout the project to facilitate tribal participation in the planning process, with assistance from the Cherokee Tribal Planning Office, ITRE, and Kimley-Horn.

Planning Process

Typically transportation planning studies can be divided into three principal phases: preanalysis, technical analysis, and postanalysis (*3*). Outside assistance is most often sought for the middle phase—technical analysis—where most of the specialized technical analysis is performed. The initial and concluding phases—pre- and post-analysis—are most often generated locally without substantial outside assistance.

Given our focus on process, this study devoted particular attention to the initial and concluding phases of transportation planning, much more attention than would be found in most transportation plans prepared by outside consultants. Such emphasis is supported in the literature on transportation planning in Native American settings. In their study of transportation planning in poor, rural areas, for example, Hauser et al. (*4*) stress the importance of establishing local community organization and developing detailed implementation plans.

The outreach efforts in our planning process drew heavily on the work of Crain and others on transportation planning in Native American settings. With regard to the preanalysis phase, Crain (*5*) addresses how to elicit goals in a Native American community based on his transportation planning work for the Menominee Nation. In Crain's study, the work was guided by an advisory committee made up of people whom the tribal leadership felt would be interested in transportation and informed by interviews with other people who, because of their responsibilities within the tribe, would have insights into the tribe's transportation needs. Once established, this process was used to enumerate and evaluate the goals, which were then broken down into categories and listed in their order of priority (based on the number of people expressing the goal, the frequency of the expression, the range of groups expressing the goal, and the intensity of the expression).

TABLE 1 Project Organization for the Cherokee Transportation Plan

Project Management	
Primary Responsibility	• UNC Institute for Transportation Research and Education
Secondary Responsibility	• Cherokee Transportation Plan Project Advisory Committee • Cherokee Tribal Planning Office
Plan Preparation	
Primary Responsibility	• Kimley-Horn and Associates, Inc.
Secondary Responsibility	• Department of City and Regional Planning (University of North Carolina at Chapel Hill) • Department of Park, Recreation, and Tourism Management (North Carolina State University) • Departments of History and Anthropology (University of Tennessee, Knoxville) • UNC Institute for Transportation Research and Education
Process Observation and Assessment	
Primary Responsibility	• Department of City and Regional Planning (University of North Carolina at Chapel Hill)
Secondary Responsibility	• Cherokee Tribal Planning Office • UNC Institute for Transportation Research and Education • Kimley-Horn and Associates, Inc.

Drawing from Crain's work, our study devoted a high level of effort to local participation. Specifically,

- We included as many stakeholders as possible on the Project Advisory Committee (from both on and off of the reservation and including both tribal members and nonmembers).
- We relied heavily on the tribal planning staff to advise the consultant team on logistics, to offer introductions, and to set up meetings with officials.
- We conducted interviews of tribal leaders and representatives of business and citizens groups to learn about the institutional framework and the specific transportation issues.
- We held planning workshops—allowing participants to walk through a number of maps, videos, and other displays—to create a more informal, participatory forum than typical public hearings.
- We asked tribe members and visitors attending the Cherokee Fall Festival to identify transportation needs and concerns in a survey conducted by the Cherokee Tribal Travel and Tourism Office.

Throughout the project, the planning team promoted a cooperative, participatory planning process. At the outset, experts on Cherokee history and culture provided information regarding public participation and the local political process. The inaugural meeting of the Project Advisory Committee in July 1993 focused on ways to encourage local participation in the planning process. And during the summer of 1993, nine in-depth interviews were conducted with key local actors regarding transportation needs and encouraging local participation. Our efforts to encourage local participation are summarized in Table 2 and described in detail in the pages that follow.

Responses from the preliminary meetings and interviews indicated that transportation was a relatively low-profile issue on the reservation and, therefore, it would be difficult to encourage active participation in the planning process from tribal council members, business leaders, and the general public. Throughout the study period, the dominant public issue on the reservation was whether casino-style gaming could and/or should be established in Cherokee. This issue commanded local policy making and, in many ways, preempted interest in transportation planning by local leaders and tribe members.

Preanalysis: Encouraging Local Participation to Determine Goals, Issues, and Problems

Planning studies, especially those not specifically governed by a planning board or commission, are frequently overseen by advisory committees composed of appointed, interested parties. In this respect, the organization of a project advisory committee for the Cherokee transportation plan was fairly typical.

From the outset, the planning team sought the broadest possible representation on the committee, though with little knowledge of local institutions or actors, we relied primarily on Cherokee tribal planning staff to select and invite advisory committee members (see Table 3).

The committee primarily comprised representatives from tribal, adjacent local, state, and federal governments. Initially 4, and later 5, of the 15 committee members were directly affiliated with the tribe; the remaining 10 members represented outside agencies (including the Bureau of Indian Affairs). However, thanks to invitations to other Cherokee leaders to participate during the study, actual attendance by tribe members at committee meetings was about equal to attendance by other representatives. While inclusion of representatives from outside agencies was probably warranted, the ratio of "outside" committee members to "inside" or tribal members was problematic for at least two reasons.

First, and foremost, having more tribal members on the committee could have stimulated more local interest and participation in the project. Many of the key actors interviewed at the conclusion of the study reported that the transportation plan was initially viewed by

TABLE 2 Efforts To Encourage Local Participation in Cherokee Transportation Plan

Outreach Effort	Date	Outcome
Pre-Analysis Phase		
Advisory Committee Meeting	7/93	57 % attendance (8 of 14 members)
Key Actor Interviews	7/93	Five interviews
Tribal Council Presentation	8/93	Questions about project scope; member added to the Project Advisory Committee
Public Meeting	9/93	Poor attendance (4)
Key Actor Interviews	9/93	Four interviews
Advisory Committee Meeting	9/93	60 % attendance (9 of 15 members)
Technical Analysis Phase		
Local/Visitor Travel Surveys	10/93	44 local residents, 20 visitors
Post-Analysis Phase		
Advisory Committee Meeting	2/94	53 % attendance (8 of 15 members)
Tribal Council Presentation	5/94	End of a long agenda; discussion cut short by late hour
Follow-up Key Actor Interviews	5/94	Six interviews
Tribal Council Workshop and Advisory Committee Meeting	5/94	Poor Council attendance (2) and 40% committee Attendance (6 of 15 members)

TABLE 3 Composition of Project Advisory Committee

Representation	Number	Attendance
Official Advisory Committee Members		
Chief's Office, Cherokee	1	0 % attendance
Tribal Council, Cherokee	1	75 % attendance (representative changed during study)
Tribal Planning Office, Cherokee	2	100 % attendance
Senior Citizens Program, Cherokee	1	67 % attendance (added to committee after 1st meeting)
Bureau of Indian Affairs, Cherokee	1	75 % attendance (representative changed during study)
Heywood County, Waynesville	1	0 % attendance
Jackson County Transit, Sylva	1	75 % attendance
Swain County, Bryson City	1	25 % attendance
National Park Service, Gatlinburg	1	75 % attendance (representative changed during study)
Tennessee Valley Authority, Knoxville	1	75 % attendance
North Carolina Department of Transportation, Asheville	1	0 % attendance
North Carolina Department of Transportation, Raleigh	1	75 % attendance
Federal Highway Administration, Raleigh	1	75 % attendance
Federal Highway Administration, Washington	1	0 % attendance
Other Advisory Committee Meeting Attendees		
Cherokee Boys Club, Cherokee	1	50 % attendance
Hotel Operator, Cherokee	1	25% attendance
Tribal Council, Cherokee	1	50% attendance (attendance by non-committee members)

many as a study by outsiders for outsiders. The struggle to overcome this "outsider" perception was made more difficult by the relative lack of local representation on the project advisory committee.

The second problem with having fewer tribal members on the advisory committee was the relative lack of local knowledge of tribal transportation issues. For example, despite tourist access to the reservation and tourist-related traffic congestion in the summer months being primary issues addressed in the plan, there were no representatives from the Tribal Travel and Promotion Office or from the reservation hotel-motel operators. Nor was there, initially, a representative from the local transit service for the elderly and handicapped.

A representative from the local elderly and handicapped van system requested participation in the study and was added after the first advisory committee meeting. The addition of this representative from the Cherokee Senior Citizens Program to the advisory committee is an interesting story of the input of cable television to public participation. The director saw the initial project presentation to the tribal council by the consultants on the local public-access television station. Concerned at being excluded from a study directly related to her work, the senior center director drove immediately to the Council House and, while the consultant presentation was still in progress, addressed the council and asked to be included in the study. She was immediately added as a member.

As a rule, the outside members, with a few exceptions, played less active roles in the meetings. Most tended to observe and comment only on issues that related to the agency they represented. Perhaps not surprisingly, the tribal representatives tended to be more active participants. In follow-up interviews at the conclusion of the study, at least two tribal committee members admitted to not fully understanding the purpose of the study or the role of the advisory committee. And the meandering discussions in many of the meetings, though often fruitful and informative, confirmed this confusion.

Technical Analysis Phase

The technical analysis process was quite straightforward, though no formal travel demand modeling was performed. Perhaps typical of transportation planning in small towns and rural areas, the land use, traffic, and accident data were often incomplete, limited, or otherwise unusable, which constrained the scope of the analysis somewhat. In particular, the lack of existing detailed land use data and the uncertain possibility of future large-scale gaming on the reservation rendered all forecasts of future traffic levels quite speculative.

Demographic data were available through the U.S. Census and the Tribal Planning Office. Tourism data were provided by the North Carolina Department of Commerce. Data on the street and highways system came from tribal maps, the Bureau of Indian Affairs, the North Carolina Department of Transportation (DOT), previous reservation transportation plans, and the current North Carolina Transportation Improvement Program. Finally, travel information was supplemented with travel survey data.

Using the *Highway Capacity Manual* (*6*), the consultants estimated current peak traffic congestion levels (expressed in terms of "roadway levels of service") at 11 locations throughout the reservation. They then used population growth, tourism projections, and the travel survey data to estimate traffic levels for the year 2015 and calculate future roadway levels of service. The results, quite predictably, showed that already severe peak tourist season traffic congestion will likely worsen considerably in the coming years without substantial capacity improvements on key roadways.

Interestingly, a number of transportation problems, unique to the Cherokee Reservation, arose during the interviews and public meetings that would have been difficult to identify though standard aggregate data sources and analytical techniques. For example, pedestrian travel was a frequently cited problem, somewhat of a surprise for a small town with a widely dispersed, largely rural residential population. Respondents to the travel survey identified "no place to walk" as the single biggest transportation problem on the reservation. Relatively low incomes, low levels of automobile ownership, frequent "casual carpooling" with relatives and neighbors, and a cultural tradition for walking combined to make pedestrian travel—particularly among the young and old—a far more common means of travel than is found in most small towns and rural areas. The general absence of sidewalks and shoulders along reservation roads forces people to walk in the traffic lanes and results in proportionally high numbers of pedestrian accidents and fatalities. As a result, lack of sidewalks was considered an important transportation deficiency by local residents. (State transportation policy, by contrast, considers sidewalks on state roads an enhancement and not an integral part of the state roads system.)

From this combined quantitative-qualitative work, the consultants prepared a technical memorandum documenting the analysis and identifying a list of transportation deficiencies that were then organized into a list of four major categories during committee discussion (Table 4). These categories differed from those in traditional transportation plans in that they included a number of community policy issues as well as deficiencies in transportation infrastructure and maintenance.

TABLE 4 Transportation Deficiencies Identified in the Technical Analysis Phase

Downtown Cherokee Area
Parking issues (on-street parking, fringe parking)
Intersection improvements, including signalization
Capacity deficiencies (congestion)
Sidewalks and pedestrian facilities
Major Roads Approaching Cherokee
Capacity deficiency on US 19 (the principal east-west highway)
Capacity deficiency on US 441 north (the principal north-south highway)
Safety improvements on US 19 (passing lanes, guardrails, etc.)
Sidewalks on US 441 and US 19
Welcome centers, rest areas
Local Streets and Roads
Street name signs
Paving program for unpaved streets
Provisions for pedestrians and bicycles
Local street maintenance program
Bridge repairs and replacements
Policy Issues
Downtown redevelopment
Land use planning
Development standards (site plan and driveway reviews, traffic impact studies, etc.)
Sidewalk policy
Residential driveway design and maintenance
Public transportation
Continuing transportation planning

Postanalysis Phase: Solutions and Strategies for Implementation

Following the recommendations of Crain (*5*) and Anding and Fulton (*7*), the plan devoted considerable attention to the postanalysis phase, particularly the implementation of recommended solutions. A number of transportation-related plans have been prepared for the reservation over the years, but these plans—all of which were prepared by outside consultants or agencies—have been relegated to the shelf and do not appear to guide current transportation or development activities. To overcome the problem of implementing transportation plans, the current plan identifies specific improvement projects to be undertaken for each of five issue areas defined in the plan. Each project identified included a description, estimated cost, estimated implementation time, and, importantly, the institution or institutions (i.e., tribe, BIA, North Carolina DOT, etc.) responsible for project implementation.

Given the problem or issue list developed during the technical analysis phase, the goal of the final phase of the plan was to solicit input on the list, prioritize the issues, develop a set of specific projects to address each of the prioritized issues, and, finally, develop an implementation strategy for each of the projects. This final goal—an implementation plan within the plan—was critical given the failure to implement most of recommendations in previous plans.

Summary

The outreach efforts in this planning process were clearly a mix of successes and failures. Efforts to reach and include individuals—key actor interviews and travel surveys—clearly worked best. Next best were the advisory committee meetings; these small group settings were fruitful but unevenly attended. Least successful were the formal presentations and large meetings—Tribal Council presentations, public meetings, and the Tribal Council workshop. Despite the persistent efforts of the project team to pursue such forums, they stirred very little interest or participation.

Under the institutional conditions encountered on a reservation, it is difficult to carry out a standard transportation planning process collaboratively with a tribe. As previously outlined, such efforts are plagued by past intergovernmental tensions, a tradition of grant seeking as a substitute for long-range planning, and a lack of tribal commitment to transportation plans prepared by outside consultants. In addition, other likely problems are

- Low priority for transportation planning, relative to immediate tribal issues viewed as more pressing, so that leaders will be reluctant to devote time, attention, and resources to plan preparation.
- Lack of interest in the abstract planning process itself, which requires progressing through sequential steps of technical inventory and analysis to make recommendations, so that attention focuses on the funds allocated to the planning process and its outputs rather than on the critical intervening decisions.
- Absence of land use regulations, such as zoning, subdivision regulations, and design standards to implement plans and provide a continuing basis for organized development of reservation lands. Instead elected officials allocate land on request for residential use and negotiate short-term leases for commercial use; the resulting projects are often poorly designed and uncoordinated with little or no consideration of parking, access, or traffic.
- Difficulty by outside consultants and transportation planning bureaucrats in understanding differences between transportation politics on reservations and in other American communities, so that incorrect basic assumptions are not challenged and "standard" practices are not properly adapted, until late in the planning process when the critical lessons have been learned by both tribal planners and outside consultants.

To overcome these and other problems encountered on Indian reservations, we believe it is necessary to revise and expand the traditional transportation planning process. Our approach seeks to fit transportation planning more closely into the conditions of the tribal setting.

STRATEGIC PLANNING: A RECOMMENDED MODEL OF EFFECTIVE TRANSPORTATION PLANNING IN NATIVE AMERICAN SETTINGS

Transportation planning is both an art and a science. It is an art in that goals, objectives, problems, and issues are difficult to define, and consensus is a challenge to achieve. It is a science in that established methods and techniques exist to analyze existing transportation systems and forecast changes. Traditionally in transportation planning, the "art" has been the responsibility of the local planners and "science" the domain of the outside consultants. The role of the outside consultants, in other words, has usually been confined to the technical, analytical side of transportation planning.

From our experience of preparing a transportation plan for Cherokee, North Carolina, we emphatically believe that this traditional division of labor between local planners and outside consultants does not and will not work in Native American settings. Unless there exists in-house transportation planning expertise on the reservation and local commitment to comprehensive planning, we suggest that an alternative, strategic approach be adopted for transportation planning on Indian reservations.

And given that a principal goal of ISTEA is an effective *collaborative* intergovernmental planning process, the planning approach used must fulfill some basic requirements:

- A collaborative transportation planning process must be treated as a "new idea" that is introduced to the tribe, marketed to key local stakeholders, and carried out as an innovation that requires the acceptance of behavioral change.
- One or more tribal leaders and staff members must be enlisted as "champions" of transportation planning, lending their prestige and status to the activity to give it a high priority on the tribal agenda.
- The plan must be conceived as a combination of short-range visible projects and long-range system improvements, to demonstrate its practicality and usefulness and to create a multiyear implementation program relying on various transportation suppliers (BIA, FHWA, state DOT, etc).
- The technical transportation work must be enlarged to include participatory methods that engage tribal leaders in all phases of the planning so that dialogue is maintained throughout and tribal values and perspectives are respected.

We recommend an approach that combines the traditional, time-tested technical planning process with elements of a more strategic planning process. Strategic planning originated in the private sector, and has been adapted to a number of public-sector planning situations. As proposed by Bryson and Einsweiler (*8*), strategic planning involves the following:

- Issue or problem focus to deal with recognized community concerns
- Participatory agenda framing and decision making by stakeholders
- Strategic, near-term implementation focus; and
- Consideration of both external and internal influences.

The standard transportation planning approach consists of three phases—preanalysis, technical analysis, and postanalysis (*3*). Each of these includes several tasks, though typically the most effort is expended in the technical analysis tasks:

1. *Preanalysis*
   - Problem or issue identification
   - Goals and objectives formulation
   - Data collection
   - Alternatives generation
2. *Technical analysis*
   - Traffic projection modeling
   - Deficiency assessment
   - Capacity and level of service modeling
   - User surveys
3. *Postanalysis*
   - Alternatives evaluation (economic and noneconomic)
   - Recommendations
   - Implementation
   - System monitoring

The typical strategic planning approach consists of eight tasks (*9*). As adapted to illustrative reservation concerns, these tasks consist of

1. *Forging initial agreement to collaborate:* making a plan for planning to which both tribal and related stakeholders are committed;
2. *Identifying mandates:* from laws such as ISTEA or the Indian Self-Determination and Education Assistance Act (PL 93-638);
3. *Preparing mission and values statements by stakeholders:* attempting to include all those with claims on reservation resources;
4. *Identifying external opportunities and threats:* such as gaming proposals, tourism and travel trends;
5. *Identifying internal strengths and weaknesses:* such as past transportation plans, conflicts with BIA, and the like;
6. *Agreeing on high-priority, strategic issues:* such as decongesting or increasing safety on main roads;
7. *Describing the future vision of success:* such as a reservation where both Indian and tourist travel is multimodal, safe, efficient, and pleasant; and
8. *Developing strategies:* practical alternatives such as lobbying for inclusion of tribal road improvements on state transportation improvement program.

We recommend that these tasks, combined with those of the standard transportation planning approach, be carried out through a series of parallel steps with the technical work feeding into the strategic planning process. Some steps can accomplish more than one task; other tasks may be spread out over more than one step. The focus for all the steps is the *transportation system*—the combination of physical facilities and organizations that provide transportation services.

The parallel tasks in a strategic transportation planning approach are shown in Table 5.

The techniques include both the standard technical methods of the transportation planner and the public involvement methods of the strategic planner. Since transportation planning practice is well established, we focus more on the public involvement methods, which are nicely summarized in *Innovations in Public Involvement for Transportation Planning* (*10*).

It is important to note here that strategic planning does not replace, but complements, the standard analytical techniques of transportation planning, such as travel forecasting, level of service determination, and traffic impact analysis. Without an institutional framework for planning—a context to make use of such technical analyses—the analyses become irrelevant and the plans that contain them gather dust on the shelf.

Since many of the strategic planning elements are related to ongoing events, the process should not be visualized as a mechanical sequence, but rather as a dynamic learning process in which some steps may be repeated as new information or insights emerge. Instead of a linear sequence, the approach could be conceived as a *strategic learning loop* (Figure 1) that could be entered at various points and pursued in various patterns, including returning to an ear-

TABLE 5 Proposed Integration of Strategic Planning with Standard Transportation Planning Practice on Indian Reservations

Traditional Model	*Strategic Model*
1. Pre-Analysis Phase	1. Organize for Planning
	2. Identify Mandates
	3. Prepare Mission/Values
2. Technical Analysis Phase	4. Analyze External Environment
	5. Analyze Internal Environment
	6. Agree on Strategic Issues
3. Post-Analysis Phase	7. Envision Future System
	8. Formulate Strategies and Plan

FIGURE 1 Strategic learning loop.

lier step if necessary. The significance is not in rigidly following the steps but in engaging and educating the stakeholders through an ongoing, participatory process leading to a plan.

What we advocate here is a strategic *process* that creates an environment in the unique setting of the reservation where effective transportation planning can occur. This strategic approach radically alters the role of the transportation planning consultant: from hired gun to planning advocate, and from technical expert to technical expert *and* process facilitator. Our experience has convinced us that the strategic planning approach offers an ideal vehicle to develop local interest, promote tribal participation and control, facilitate effective analyses, and increase implementation in the unique social and institutional settings on Indian reservations.

POSTSCRIPT: BUILDING IN-HOUSE PLANNING SKILLS

An important lesson from the Cherokee case study is that tribes frequently lack both the technical and the strategic planning skills to carry out effective transportation planning. This makes them dependent on outsiders for these skills. And this dependence reproduces dependence through time. The obvious solution to this cycle of dependency is to build the skills base within the tribe to make transportation (and other related forms of physical planning) an ongoing part of tribal practice. Tribal planners with transportation planning skills can make transportation planning part of the daily fabric of reservation activities and place it high on the tribal agenda. Some investment now in transportation skills building for Native Americans will have a high future payoff in terms of much more efficient and effective reservation transportation systems.

To remedy the lack of technical and strategic planning skills, we recommend that the federal government create a professional transportation education program and market it to Native Americans desiring to pursue planning careers. The program would consist of apprenticeships for high school students and scholarships and fellowships to university degree programs in transportation, urban, and regional planning. $200,000, for example, would train 12 Native American planning fellows each year. Selected fellows would receive mentoring for practice-oriented degrees at both the bachelor's and master's level. During the summers, they would serve internships in tribal planning and transportation offices, as well as in state DOT and BIA offices. Following completion of their education programs, they would be expected to return to the reservation for at least 2 years, where they would be attached to the tribal planning office. Finally, workshops could be held for tribal planners and elected officials on project management and institutional arrangements.

Such a program would be entirely consistent with both the Indian Self-Determination and Education Assistance Act and ISTEA and would remedy many of the problems with transportation planning consulting on Indian reservations by, over time, rendering them moot.

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Least-Cost Planning: A Tool for Metropolitan Transportation Decision Making

DICK NELSON AND DON SHAKOW

A new approach to transportation investment planning and a prototype sketch-planning model are described. The model was developed to assist metropolitan transportation planners and decision makers in meeting the new federal and state planning requirements. Based on two decades of experience in electrical energy planning, the model incorporates the principles of least-cost planning and full-cost accounting. It attempts to promote an efficient search for investment and policy strategies that enhance regional benefits, while reducing social costs. A demonstration of the model for the Puget Sound metropolitan region was carried out by comparing a limited number of options. These included a set of study options associated with a proposed light rail system, two commuter rail options, an option featuring the construction of a regional bicycle network, a highway expansion option, and a series of options emphasizing public and private incentives directed toward reduced single-occupancy vehicle use. Further refinements of the model will allow for the accounting of synergy among options, the comparison of decision packages, and the selection of an optimal and integrated set of investments and policies.

Under new federal and state planning requirements, regional planners and decision makers must assess the cost-effectiveness of a broad selection of transportation modes and policy options. Demand management strategies must be given equal consideration to highway and transit capacity enhancements. Pedestrian and bicycle modes must be allowed to compete on an equal basis with motorized modes. Costs, including indirect social and environmental costs, must be fully accounted for. And planning must recognize the reality of increasingly constrained revenues.

Traditional planning and decision-making tools were not designed to accomplish the comprehensive and integrated analysis now required. New tools must be devised that allow a broad comparison of modes and management strategies to identify the most cost-effective alternatives.

Metropolitan planning organizations and transportation decision makers face difficult challenges as they begin to address the requirements of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), the Clean Air Act Amendments of 1990, and, in an increasing number of states, legislation directed at management of growth. These challenges include provision for expanding mobility and access needs, management of congestion, integration of transportation investments and land use policies, and mitigation of air quality and other environmental impacts.

All of this must be accomplished in the context of fiscal constraints, especially regarding the available level of federal assistance that continues to decline as a share of all public transportation expenditures.

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Planners and decision makers must also adjust to the ISTEA requirement that funding be more flexible. This will probably mean that transit and alternative travel modes, such as ride sharing, walking, bicycling, and telecommuting, will receive a larger share of available revenues. The concept of flexible funding must encompass the reality that traditional solutions involving major capacity investments, even transit investments, which use up scarce resources, may make less costly but more beneficial, solutions impossible to finance.

ISTEA, in fact, recognizes this imperative by requiring that the metropolitan planning process analyze the cost-effectiveness of alternative investments in meeting transportation demand and the ways transportation needs may be met by using existing transportation facilities more efficiently. The cost analysis requirements for major investments in highways and transit systems are even more specific. A major investment study (MIS) must evaluate the cost-effectiveness of alternative investments or strategies, and it must consider the indirect as well as the direct costs of reasonable alternatives. The MIS must take into account social, economic, and environmental effects; operating efficiencies; land use; economic development; and energy consumption, among other factors.

Clearly, cost must be an object of metropolitan transportation planning in a way that it has not been previously. New analytic tools must be devised that allow for cost and benefit comparisons across all feasible alternatives, whether new capacity investments or management strategies. External and indirect costs, as well as direct development and operation costs, must be considered.

Recent studies have compared the application of least-cost methods to energy planning with its potential application to transportation planning (*1–3*). These authors, while pointing to differences as well as similarities between energy and transportation, encourage the belief that the least-cost methodology, which has been highly refined and widely applied to energy, could be successfully translated to transportation.

Two authors who have contributed to the development of least-cost planning as it is practiced in the Pacific Northwest electric power industry, Ed Sheets and Dick Watson, observe a number of important analogies between the domains of energy and transportation that make both fitting candidates for least-cost planning (*3*). Both energy and transportation can benefit greatly from an analytical process by which demand-side resources are given consideration equal to the construction of facilities and infrastructure. In both cases, a full survey of options would highlight approaches to system design and management that could result in far lower costs than merely expanding capacity.

In addition, energy and transportation both require a full accounting of levelized life-cycle costs, including direct capital costs, environmental costs, time costs, and preference costs. Least-cost planning mandates this degree of rigor in cost accounting.

Sheets and Watson also suggest that both energy and transportation must deal with an uncertain future. Demand for both transportation services and electricity are subject to unknown changes in technology, behavior, and economic constraints. Transportation planning could benefit from the flexibility to adapt to uncertainties that has been incorporated into electricity least-cost planning.

As noted earlier, a major challenge for transportation planning under the new planning rules is to assess the impact of a broad set of options on mode choice and then to assess all significant costs over all mode choices. The aggregate social cost associated with various options can then be computed.

An approach that can treat alternatives and costs in this way has been outlined by federal highway and transit researchers (*4–6*). Patrick DeCorla-Souza and Ronald Jensen-Fisher note that an integrated approach has been impeded historically for highways and transit by the use of different measures of effectiveness for each mode. Also, significant costs have been omitted. Transit cost accounting omits the cost of roadway use by buses, while highway cost accounting excludes vehicle ownership costs and the costs of parking. External social and environmental costs are ignored in all instances. The authors stress the importance of full-cost accounting to avoid favoring certain modes.

Least-cost planning is beginning to attract the attention of transportation decision makers. The Washington State legislature in 1994 enacted legislation that requires regional transportation planning organizations to use a least-cost planning methodology in formulating regional transportation plans (Substitute House Bill 1928, 1994). The methodology must identify the most cost-effective facilities, services, and programs.

If a least–full cost approach is to be useful, it must be more than just a planning tool; it must be capable of assisting decision makers who must often make tough choices in a highly political environment.

This paper describes a new least–full cost sketch-planning tool for application to metropolitan area transportation planning and investment decisions. With appropriate data, the tool would also be useful for subarea and corridor decision analyses.

SUMMARY OF LEAST-COST PLANNING

Least-cost planning (LCP) refers to an analytic procedure that incorporates the following elements and procedures:

- The process attempts to maximize the number and range of transportation alternatives on the table. No credible approach is ruled out a priori.
- The method is neutral among alternatives. Any element of subjectivity that would favor one alternative over another is minimized.
- A standard of performance is specified over a planning period. An example of such a standard would be a required level of regional accessibility and mobility. All transportation strategies to be compared within the framework of a least-cost analysis are constrained to achieve the required standard of performance.
- Under LCP, the standard of performance can be defined with some degree of flexibility and latitude. Where a given standard poses problems of measurement, other surrogate standards can be developed and the cost of alternative strategies can be compared as long as they achieve the surrogate standard. For instance, if general accessibility measures in transportation are deemed too difficult to measure, more concrete standards—for example, congestion reduction, reduction in single-occupancy vehicle mode, etc.—can be substituted. If appropriate, a group of these standards can be designated, aggregated, and weighted as an accessibility index. This flexibility contrasts with other approaches (e.g., benefit-cost analysis) where the standard (net consumer utility) is predetermined.
- An efficient search among alternative strategies is conducted to determine that strategy or set of strategies that minimizes net social cost (alternatively, that maximizes net social benefit).
- A preferred strategy must account for alternative futures and the risk that current expectations may not be fulfilled. The process incorporates significant elements of uncertainty and risk:
  - –The standard of performance (e.g., regional accessibility and mobility requirements) depends on the level and character of regional growth, which cannot be known with certainty.
  - –The evolution of transportation and communications technology is a significant (and highly dynamic!) unknown over a 20-year or more planning horizon.
  - –The future economic environment—prices, employment, currency fluctuations, industrial mix—is difficult to predict.
  - –The future regulatory environment depends on political developments that are currently unknown.

LEAST-COST PLANNING AS A PRACTICAL DECISION TOOL

In considering the elements of a transportation model based on economic principles, it is essential to highlight those aspects that make it suitable in the context of planning as opposed to pure research. Planning is meant to inform political policy making and public decision making. Transportation investments are likely to continue whether or not they are informed by planning models. Models should be designed to maximize the probability that decisions will be in the public interest over the long haul. And, models should provide a quantitative framework for comparing alternatives at a level of precision sufficient to inform decision makers and account for the considerable uncertainty that pervades any attempt to forecast transportation options and behaviors.

Though a number of alternative investment analysis tools exist—including benefit-cost analysis and multiobjective analysis—least-cost planning, based on the energy experience and incorporated in a sketch-planning model, has the following unique advantages:

- It is easily comprehensible to policy makers, interest groups, and voters.
- It is fast and easy to implement at a useful level of approximation.
- It is neutral and unbiased with regard to outcomes.

FRAMEWORK OF THE LEAST-COST PLANNING MODEL

The least-cost planning model (LCPM) was designed (*7,8*) to identify a package of transportation options for a study area satisfying the following criteria:

- The package meets the access needs of the area for a variety of trip purposes and special populations.
- The package results in a maximum net reduction in social cost compared with a no-action base case.

- Costs are inclusive of private costs, government subsidies, environmental and pecuniary externalities, congestion, and other travel time costs.
- The range of options surveyed is complete, inclusive of transportation system management (TSM) and transportation demand management (TDM), and various ride sharing, transit, low-powered and nonmotorized modes.
- The optimal package accounts for synergies among options and for the time path over which the options are implemented.

In so far as the LCPM is designed to reduce the cost of meeting transportation needs, it can be regarded as a tool to enhance net social benefit, rather than simply least cost. The term "least-cost model" provides terminological continuity with energy prototypes, but suggests a too limited notion of what this model aims to achieve.

Model Description

A schematic description of the LCPM is shown in Figure 1. The exogenous driver is *access*, which is defined as a condition wherein individuals with the requisite economic means overcome the limitations of space that would otherwise impede the fulfillment of an economic objective. Access, in the context of this definition, is defined in units of potential trips. In a typical instance, access involves movement and takes the form of *mobility.* An expanding telecommunications infrastructure facilitates *telecommuting* or other activity allowing access to the work site while lessening the mobility requirements associated with traditional commuting.

The LCPM allows for the possibility of achieving access through nonmobility or reduced mobility options. For each trip purpose or special population (see Figure 2), access is discounted by variables that reflect the future incidence of means to achieve access without resort to mobility. The generalized form of these relations is as follows:

$$\textit{mobility (trips)} = \textit{access} \times \textit{discount factor}$$

Mobility, as implied in the equation is measured as a vector of trips by trip purpose.

The objective is to compare costs over the universe of option packages. Costs are typically determined as the product of some measure of transportation activity and the cost per unit of this activity. A crucial question arises in this regard: What is the measure of activity appropriate to a least-cost transportation model? Several candidates suggest themselves:

- The number of person trips,
- Vehicle counts,
- Person kilometers of travel (PKT) defined as the product of trips and average trip length, and
- Vehicle kilometers of travel (VKT) defined as PKT divided by the average occupancy rate per vehicle.

In distinguishing among these measures, it is necessary to keep in mind the practical distinctions that occur among options. For example, VKT is inadequate as a sole basis for measuring transportation activity since it would fail to distinguish adequately among options that highlight vehicle occupancy rates, such as those that involve high-occupancy vehicle (HOV) lanes. By contrast, where congestion costs are at issue, traffic volumes and vehicle counts, or, in some instances, VKT, are more appropriate. Options that highlight trip reduction in the face of constant access would focus on number of trips. Thus, no single measure of transportation activity is appropriate in the LCPM, but rather a vector of measures.

Trips multiplied by trip length yields PKT in aggregate (across modes). Trip length is a crucial variable in the efficient search for a least-cost package in that many long-term transportation options focus on land-use regulation. Growth management policies that limit the extent of development and that emphasize mixed use and higher density living implicitly target trip length reduction as a goal.

Mode choice is a major consideration in defining transportation options. The LCPM distinguishes among 20 modes as indicated in Figure 2. The model allocates PKT by trip purpose among modes using a multinomial logit specification for each distinct trip purpose (or special population). It computes the probability of an individual selecting a given mode for a particular trip purpose. This probability is a function of the following variables:

- Direct internal cost of travel per PKT by mode,
- Travel time per PKT by mode, and
- Real income.

Once mode choice probabilities are determined, total PKT is allocated among modes. Information on occupancy rates per vehicle allows the inference of VKT.

Estimation and Treatment of Costs—Sources and Methodological Observations

The LCPM is a full-cost model that attempts to account for all significant costs, internal and external, public and private, monetized and nonmonetized. (Travel time is an instance of a significant cost that is not monetized.) This objective raises the level of uncertainty associated with model outcomes. While some cost elements are easily computed, others are subject to controversy. The elements subject to the most uncertainty include the various components of environmental cost, land-use costs, congestion and travel time cost, and costs related to the achievement of such social objectives as equity. A complete list of cost categories and their categorization is shown in Figure 2.

Some observers have suggested that costs other than those associated with real-life monetary transactions be omitted from policy-oriented analyses due to their inherent uncertainty and poorly understood theoretical foundations. While conceding the embryonic nature of work in this area, it would seem reasonable to include as many of these costs as possible. The attempt to quantify environmental, social, and temporal costs reflects a need to assess their social importance compared with those costs that are quantified explicitly by market mechanisms. Without such quantification, transportation and land use decisions are necessarily biased in favor of those factors that enter an explicit market calculus. Where reasonable people might disagree over the specific magnitude of costs, process mechanisms can be devised to achieve compromise and consensus within specific planning jurisdictions.

Considerable recent effort has been directed at gaining an understanding of the full costs of transportation (*9–13*). A recent study sponsored by the Conservation Law Foundation (*10*) estimates costs across several modes for the components employed within the LCPM. Other recent studies by Litman (*11*) and Miller and Moffat (*12*) cover similar ground, though estimates differ.

The authors were confronted with the problem of choosing among three or more competing estimates. The cost data used in the LCPM

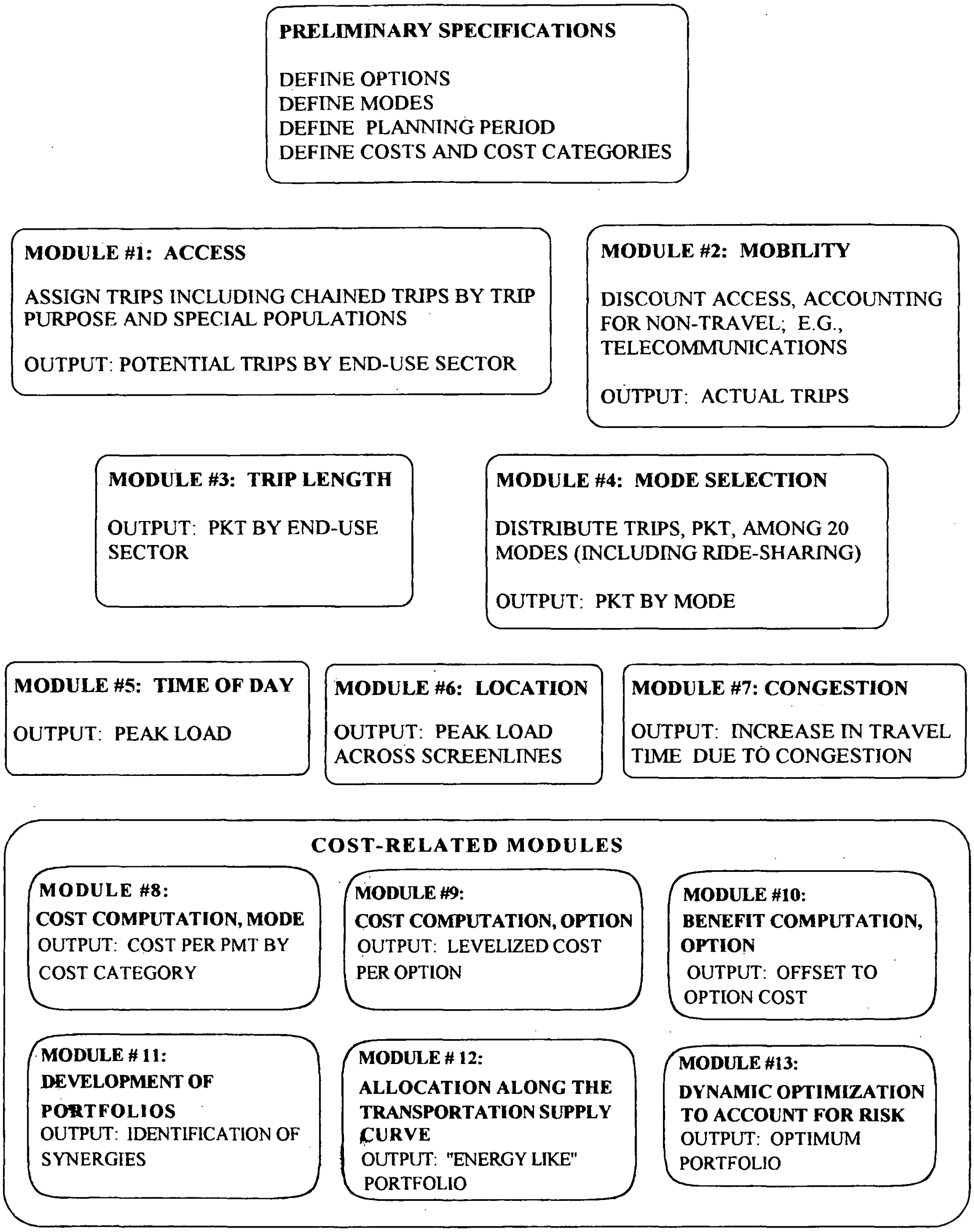

FIGURE 1 Least-cost planning model structure.

application base are based primarily on Litman since he has made the most complete review and comparison of the literature on costs.

The costs for various categories are summarized in Table 1. These values are continually being revised as new studies and theoretical arguments become known.

Travel Time Costs

A significant issue concerns the reckoning of travel time as a social cost. The Conservation Law Foundation study omits all noncongestion travel time costs, arguing that "when deciding to make a trip, a driver implicitly considers his or her own time costs of the travel" (*10*, p. 12). In general, economists do not account as costs the time required to perform such personal tasks as mowing the lawn and washing the dinner dishes. In the case of travel, however, there are compelling reasons to break with this tradition and to impute a cost to the time required to travel. Given a choice between two alternative modes that require significantly different travel times, the traveler is likely to choose the more expeditious mode, all other things being equal. This is an economic calculation.

TRIP PURPOSES AND SPECIAL POPULATIONS

WORK
SHOP
CHILD CARE
SCHOOL
SOCIAL/RECREATIONAL
TOURISM
ELDERLY
DISABLED
BUSINESS
COMMERCIAL HAUL

CHAINED TRIPS:
WORK/SHOP
CHILDCARE/WORK
CHILDCARE/WORK/SHOP

MODES

SOV
2-PERSON CARPOOL
3-PERSON CARPOOL
4+-PERSON CARPOOL
VANPOOL
BUS
PARA-TRANSIT
TAXI
PEDESTRIAN
BICYCLE
MOTORCYCLE
2-WHEELED LOW-POWER VEHICLE
SCHOOL BUS
FOOT FERRY
COMMUTER RAIL
RAPID RAIL
LIGHT RAIL
FLEET VEHICLE
LIGHT TRUCK
HEAVY TRUCK

COST CATEGORIES

Internal Direct Costs:
- VEHICLE
- FUEL
- INSURANCE
- REPAIR
- TAXES
- INTEREST
- TRANSIT (VANPOOL) FARE
- INTERNALIZED PARKING
- INTERNALIZED ACCIDENT

Indirect and Public Costs:
- ROAD (RAIL) BED REPAIR
- OPERATIONS AND MAINTENANCE
- LOCAL SERVICES (E.G., TRAFFIC CONTROL, ROADSIDE DISPOSAL)
- TRANSIT DIRECT ENERGY
- INDIRECT ENERGY (E.G., ENERGY USED IN HIGHWAY CONSTRUCTION)
- ENERGY SUBSIDIES (E.G., NATIONAL PETROLEUM RESERVE)
- SUBSIDIZED PARKING

External Costs:
- ACCIDENT
- NOISE
- BUILDING VIBRATION DAMAGE
- LOCAL AIR POLLUTION
- GLOBAL AIR POLLUTION (E.G., ACID RAIN, GLOBAL WARMING, OZONE DEPLETION)
- WATER POLLUTION
- LAND LOSS (INCLUDING WETLANDS)
- PECUNIARY EXTERNALITIES DUE TO INCREASES IN PROPERTY VALUES
- EQUITY (E.G., SPECIAL FACILITIES FOR HANDICAPPED)

Time-Related Costs:
- TRAVEL TIME
- CONGESTION

FIGURE 2 Trip purposes, modes, and cost categories used in least-cost planning model.

It has been claimed that the inability of public transit to increase its proportional share of ridership lies in the common perception (and often the reality!) that transit trips (including access times, wait times, and transfer times) absorb considerable time compared with automobile trips. Such nondelay-related travel time is appropriately factored into the overall calculation of transportation-related social cost. If such costs were omitted, the social cost of, say, land-use patterns that encourage home-based work trips of ever-increasing length and travel time is likely to be underestimated.

A condition where one-quarter to one-third of nonsleep, nonwork time is devoted to travel for many commuters cannot be regarded with indifference from an economic perspective. The LCPM, for these reasons, includes travel time as a cost and attempts to monetize these costs. In taking this position, the study team has followed the general practice of the British Columbia Ministry of Transportation (*13*), which accounts travel time costs for commercial and noncommercial drivers and for passengers of various age groupings.

Congestion Cost

Congestion cost is an important constituent of total social cost. Indeed, the public often perceives the level of congestion as a principal index of how a regional transportation system functions. Moreover, the existence of congestion cost as a classic instance of market failure has been recognized and acknowledged by economists for many years.

Estimating congestion cost presents (at least) two difficulties in the context of the LCPM. A first problem involves translating time to dollars. The cost of delay clearly differs from person to person and from situation to situation. Bus riders are likely to represent lower-income travelers compared with single-occupancy vehicle (SOV) riders. Does this imply that the congestion cost of the former (approximated by their lost wages) is lower than that of the latter? In principle, it would be appropriate to stratify this cost by traveler characteristics; but for the present iteration of the LCPM, an estimate from Litman that averages over a range of characteristics was used.

A second problem involves the estimation of hours of delay for a metropolitan region. The LCPM attempts this without employing a detailed network or zonal model. System performance as measured by hours of delay is a major output of conventional travel demand modeling. Ideally, the apparatus of such models could be appropriated and integrated with a least-cost model. This integration has been suggested in the Puget Sound metropolitan area (*14*).

TABLE 1 Examples of Costs for Single-Occupancy Vehicles and Transit Employed in Least-Cost Planning Model

Cost Category	Cost (1994 Cents/PKT)
Private Internal Direct Costs:	
Vehicle capital	8.6
Vehicle fuel	3.8
Vehicle insurance	4.8
Vehicle repair	2.9
Vehicle taxes	1.1
Bus transit fare	4.3
Parking	2.6
Accidents	3.2
Indirect and Public costs:	
Road construction and repair	1.7
Local road services	0.7
Vehicle energy subsidies	0.9
Subsidized parking	7.5
Subsidized accidents	2.2
Subsidized bus capital	5.7
Subsidized bus O&M	27.7
External Costs:	
Noise	0.6
Local air pollution	2.8
Global air pollution	0.6
Water pollution	0.8
Land utilization	1.5
Property values	2.8
Time-Related Costs:	
Travel time	13.0
Congestion	5.7

In our simplified approach, regional congestion is estimated using a finite number of the highest-volume corridors. Congestion in these instances is a function of present and projected traffic volumes and system capacities produced by regional planners. These estimates are employed as an index for approximating congestion for the overall study area. The decision to abstract from the network detail is based on the view that congestion, in practice, is concentrated in well-defined corridors and that the margin of error associated with the omission of estimates for less congested corridors does not significantly affect the overall calculation of congestion cost for the study area.

Net Social Benefit Calculation

The net social benefit associated with a package of options is defined as savings less implementation cost. Savings are calculated relative to a base "no action" case. The model first calculates real discounted cost (using a 3 percent social discount rate) for the base case over a user-defined planning horizon. It then introduces a series of options in succession. Options in some instances may combine several technological, policy, or institutional elements as a package. The net benefit of all options are then ranked. Options are then introduced in succession working down an "option stack" until marginal net benefit is no longer positive.

Disaggregation of Trip Purposes and Modes

The set of trip purposes, special population groups, and modes incorporated in the LCPM are listed in Figure 2. Their selection attempts to realistically and thoroughly account for the factors that underlay the response of transportation users to a set of options.

The most recent decade has witnessed fundamental changes in the structure and characteristics of families and households. Two-earner households are increasingly the norm and single-parent households are far more common than in the past. This holds significant implications for transportation choices. Multicar ownership is often a matter of necessity, while travel patterns are often dictated by child care needs. The LCPM recognizes these trends by specifying child care as a distinct trip purpose.

Child care, moreover, is likely to result in significant trip chaining. Neglect of the phenomenon of chaining is apt to bias transportation planning in favor of public transit options. The choice of transit for chained trips is likely to involve significant travel time costs since the traveler must embark and disembark at least twice. If the chain involves child care as an element, trip quality must be taken into account as well since parents may be reluctant to carry their child onto a bus or train.

Chaining occurs in many other contexts as well. Travel to work is often combined with shopping. Eating out (perhaps in fast-food drive-ins) on the way home from work and shopping results in multiple links on the chain. A recent study of National Personal Transportation Survey data suggests the importance of chained trips as part of all travel (*15*).

To factor chained trips in the LCPM model, three prevalent kinds of chained trips have been defined (see Figure 2).

In listing trip purposes, the importance of special population groups must be emphasized. The determinants of transportation choices for elderly or disabled persons are clearly different compared with young, able-bodied individuals. The LCPM distinguishes special populations in estimating access requirements, trips, trip length, and mode choice. This, in turn, allows consideration of options that target these populations (e.g., on-demand transit for elderly and disabled persons).

In its choice of modes, the LCPM aims to be as inclusive as possible. Aside from single-occupancy vehicles and the principal public transit modes—including bus and rail (commuter, rapid, and light)—the model considers a spectrum of ride-sharing modes, taxi, nonmotorized (bicycle and pedestrian), and foot ferry (a viable option for the central Puget Sound region). Commercial modes are also considered, distinguishing fleet vehicles and (heavy and light) trucks.

MODEL APPLICATION: OPTIONS, PACKAGES, AND PORTFOLIOS

The LCPM searches among a set of distinct transportation options to configure a least-cost *package*. These options range widely from major transportation investment projects to enhancements and expansion of existing infrastructure to TSM and TDM measures that are individually modest in scope, but that offer a significant impact when bundled with other measures.

Application of the model to the Puget Sound metropolitan area was demonstrated by employing a limited set of options and portfolios (Table 2). The options and portfolios were selected because they represent a range of supply- and demand-side measures that are under active discussion in the central Puget Sound region or in other regions.

The system design, ridership forecasts, and costs for the bus emphasis, light and heavy rail emphasis, and commuter rail options were developed by the Central Puget Sound Regional Transit Authority. Each of the demand-side options required that a cursory design be accomplished and estimates of costs and performance be made. No attempt was made to perfect the design of these options to the extent that would be necessary to propose them for adoption by decision-making bodies. The options were sufficiently outlined such that they would be accepted as feasible by transportation practitioners.

Similarly, obvious linkages and synergies between options were ignored in this test run. A real-world application would require the design of comprehensive programs involving these options as elements.

Accounting for the Political Environment

In many cases, choices among options are not determined on efficiency grounds alone. Political and other factors may require that some options be "forced" into a mix regardless of cost. In certain cases, the public may favor the implementation of a given option regardless of cost. In other instances, a highway may be located to serve the needs of a favored constituency; a rail system might be routed to avoid disrupting a locality that would otherwise delay construction by litigating. The LCPM is designed to allow for these situations, optimizing under the political and other constraints to design a second best package of options. Where this involves the inclusion of particular options without subjecting them to a benefit-cost calculus, the sets of options are termed *portfolios*.

Portfolios are also useful in assessing the costs and benefits of options that are on the table. In the central Puget Sound region, public discussion has recently centered on the relative merits of a rapid rail, light rail, monorail, bus, TSM, and TDM investment strategies, with other interests emphasizing highways, and still others non-motorized (i.e., pedestrian and bicycle) infrastructure. The LCPM can be applied to various portfolios that are constrained a priori to support these disparate emphases and interests.

TABLE 2 Transportation Options and Portfolios Included in Least-Cost Planning Model Demonstration

Options*	
19.	South corridor commuter rail
20.	North corridor commuter rail
32.	Passenger ferries
33.	Highway expansion (SR 18 & SR 522)
35.	Monorail expansion
48.	Commuter bicycle lane network
59.	HOV system completion
75.	Traveler information system
110.	Congestion pricing on SR 520
114.	Employer subsidized parking cash-out
117.	Transit passes for Commute Trip Reduction
120.	Telecommuting tax incentive
159.	Ride-share tax incentive
168.	Vanpool tax incentive
Portfolios*	
2.	RTP Rail/TSM recommended alternative
14.	RTA Study Option 1: Regional bus emphasis
15.	RTA Study Option 2: Surface rail emphasis
16.	RTA Study Option 3. Grade-separated rail

*Numbers correspond to list in Appendix A of reference 7.

RESULTS OF THE MODEL DEMONSTRATION

As previously indicated, the LCPM proceeds first by computing costs associated with a base case in which no new options or measures are adopted, but present trends are assumed to continue over a 30-year planning period. The social benefit of introducing options singly is then computed by comparing the full life-cycle cost of meeting regional access requirements under the option with the comparable estimate for the base case. This estimate of social benefit is computed net of the life-cycle cost associated with implementing the option.

Partial results of the Puget Sound demonstration are shown in Figures 3 and 4.

The LCPM has the capability of assessing the impact on travel demand of any single option or group of options. An example is illustrated in Figure 3, where single-occupancy vehicle PKT for the base case and for a grade-separated rail option are compared. The rail option was the most ambitious among those recently considered by the Central Puget Sound Regional Transit Authority. While some SOV displacement is indicated, the magnitude of this displacement is relatively small.

Figure 4 shows the breakdown between the implementation cost and the gross benefit of each of the options and portfolios that were analyzed in the LCPM demonstration. The difference between the implementation cost and gross benefit is the net social benefit.

The results indicate that the preferred combination among the 18 options and packages might involve significant expansion in bus service with limited light rail (Option 14), expansion of bicycle and pedestrian infrastructure (Option 48), HOV lane system completion (Option 59), implementation of a traveler information system (Option 75), a subsidized transit pass program (Option 117), and a ride-share tax incentive (Option 159). These results, although highly provisional, validate the proposition that there is no single dominating "fix" for an impending condition of excess transportation demand and excess social and environmental cost. Rather, the net social benefit would be greater—indeed even positive—if a number of undramatic but well coordinated synergistic measures were implemented in combination.

FUTURE WORK

To be useful as an operational tool in metropolitan planning, the LCPM requires further refinement. Model improvements will be directed to the following areas:

- Elaborating the specification of trip purposes, with a special emphasis on chained and linked trips.
- Refining the search algorithm to more efficiently compare a larger number of decision packages.

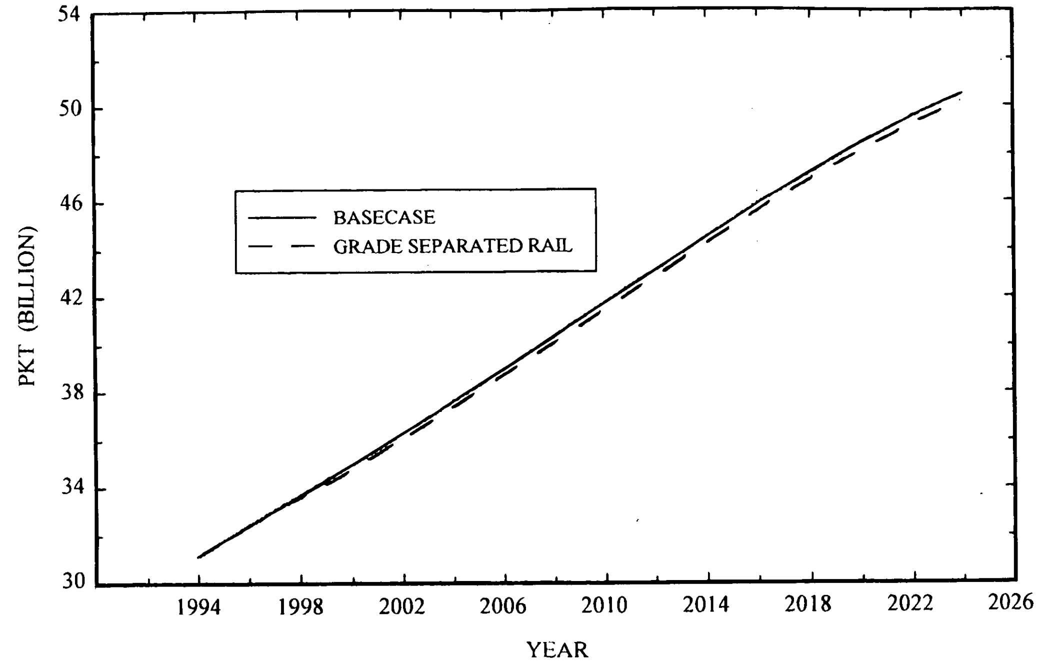

FIGURE 3 Person kilometers of travel by SOV—base case compared with grade-separated rail.

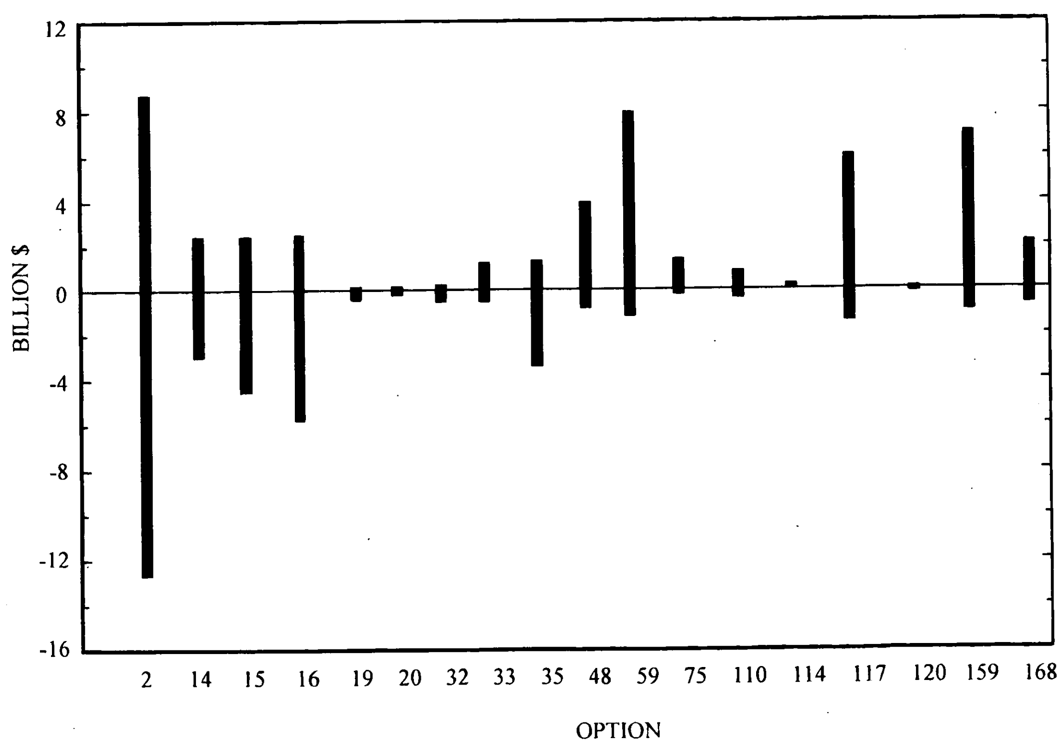

FIGURE 4 Transportation benefit (above) and cost (below) for options in least-cost planning model demonstration.

- Providing a more exact accounting of cost synergies associated with option combinations. The model formally allows for this at present, but there is little theoretical and/or empirical basis for actual estimates.
- Accounting more accurately for the timing of investments through a truly dynamic optimization procedure.
- Accounting more precisely for the direct, indirect, and induced benefits of options.
- Accounting for variability in travel demand—its relationship-changing population demographics, economic activity, technology, and land use.
- Providing a more accurate basis for estimating regional congestion.
- Providing a useful analog to the supply and demand curves employed in least-cost energy planning.
- Refining cost estimates—especially for nonmarket costs.

CONCLUSIONS AND RECOMMENDATIONS

The development of the prototype LCPM has confirmed that the objective of identifying transportation options that are of maximum social benefit to a metropolitan region is a feasible one. Moreover, the work has confirmed the essential role of this analytical tool in the search process. In the absence of such a model, the danger exists that no objective standard can be invoked to compare widely disparate options. In the transportation field—perhaps more so than in other venues—there exists an intensity of conviction among advocates that may dampen objectivity. The sheer magnitude of the expenditures involved in building a new freeway or constructing a rail system suggests that a rational economic standard should be invoked before scarce public and private funds are committed to these very costly projects. Indeed, such a cost-based methodology is required by statute under ISTEA. Once funds are committed and spent they cannot be unspent.

Professor Martin Wachs has recently commented that ". . . transport policy making is primarily a political exercise, and . . . analytic approaches by technical experts are invariably less influential than the pull and tug of influential interest groups" (*Transportation Research A*, Vol. 27, No. 4, p. 337). A least-cost planning approach attempts to provide a neutral basis that would mediate among such interest groups. Yet, for this to be achieved, a coherent analytic foundation is essential.

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Congestion Management Data Requirements and Comparisons

GRACE E. BYRNE AND SHAWNA M. MULHALL

Both the 1990 Clean Air Act Amendments and the 1991 Intermodal Surface Transportation Efficiency Act require reducing congestion to improve air quality, to use existing transportation facilities more efficiently, or to increase mobility of people and goods. Meeting these goals means identifying appropriate and realistic data for measuring congestion, facility efficiency, and travel mobility. Six congestion management and performance monitoring systems are reviewed for data types used to monitor congestion. The data found are categorized and compared to identify and recommend key data types that could be used in a congestion management system. Recommendations identify data that can be easily manipulated to produce additional informative measurements and that are likely to be available to most transportation agencies.

Managing congestion is a relatively new concept that has recently come to the forefront of transportation planning for several reasons. The first is the realization that the demand for single-occupancy vehicle (SOV) travel exceeds both local and national ability to meet that demand. That is, SOV travel demand will always exceed roadway supply. Second, because congestion results in low speeds combined with stop-and-go conditions, congestion is a major source of polluting automobile emissions, which lower air quality and raise health hazards.

Congestion also has the paradoxical effect of benefiting transit and high-occupancy vehicle (HOV) use. Transportation research indicates that congestion can benefit transit and other forms of HOV travel if HOVs have a dedicated travel lane or other form of preferential treatment. SOV congestion naturally results in slower SOV travel; the preferential treatment for HOVs results in increased HOV travel speed, making HOV travel more convenient and competitive with SOV travel.

Both the 1990 Clean Air Act Amendment and the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) require reducing congestion to improve air quality, to use existing transportation facilities more efficiently, or to increase mobility of people and goods. Meeting these goals means identifying appropriate and realistic data for measuring congestion, facility efficiency, and travel mobility.

The Management and Monitoring Systems: Interim Final Rule, which provides the implementing regulations for a congestion management system, requires "a continuous program of data collection and system monitoring" (*1*). While the ruling clearly states that existing data sources can be used, the requirement can seem daunting. An effective congestion management system can be developed by identifying key data that can be manipulated to produce other, derived measurements.

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OBJECTIVES

The focus of this paper is to identify data that could be integrated into a congestion management system. The emphasis is to identify realistic and achievable data to incorporate into a congestion management system. To be useful, the data must be both readily available and easily manipulated. Data that require intensive or extensive collection efforts were excluded, while data that form the basis of more complex measures were included. For example, average vehicle occupancy (AVO) and vehicle miles traveled (VMT) were included because these data could be simply manipulated to acquire person miles of travel. The final recommendations identify data that are likely to be currently available to most transportation agencies.

FEDERAL REQUIREMENTS

The following analysis is based on both the Management and Monitoring Systems: Interim Final Rule and on the Management and Monitoring Systems Proposed Rulemaking, which precedes the Interim Final Rule. The Interim Final Rule provides the implementing regulations for the management systems required under ISTEA, including congestion management systems. The Proposed Rulemaking, referred to as the Notice of Proposed Rulemaking (NPRM), was issued first to allow interested parties to comment on the regulations before any interim final rule was issued. At this time, a final rule has not been issued. The Interim Final Rule supersedes the NPRM, but the NPRM provided the four initial data categories used in this paper.

ISTEA requires each state to develop and implement a continuous traffic congestion management system (CMS). This system should identify and implement strategies to "provide the most efficient use of existing and future transportation facilities in all areas of the state, including metropolitan and non-metropolitan areas, where congestion is occurring or is expected to occur . . ." (*1*).

As stated in the Interim Final Rule, a CMS should have five main components: (a) performance measures, (b) data collection and system monitoring, (c) identification and evaluation, (d) implementation of strategies, and (e) evaluation of the effectiveness of implemented strategies (*1*).

The second component, data collection and system monitoring, is the focus of this report. While the first component (performance measures) can determine which data should be analyzed, understanding the data needs of the performance measures can contribute to developing effective measures. Certain key data types can be collected and then manipulated to produce additional data and analytical tools. Because additional data and tools can be generated from a few key data types, the CMS requirements can be more achievable.

The Interim Final Rule explicitly refers to monitoring recurring congestion, but nonrecurring congestion should also be addressed because it often accounts for much of the congestion. The CMS should also monitor the movement of both people and goods. If the existing or implemented data collection system does not monitor this movement, then the data collection process should be revised (*1*).

Data collected for the CMS must also be able to evaluate the ability of the implemented strategies (Component d) to alleviate congestion and increase mobility. In other words, the data must be used to measure not only congestion and mobility but also the ability of the strategies to reduce congestion and improve mobility.

APPROACH

Existing congestion management and performance monitoring systems were reviewed to identify data already being used to measure congestion. These data were then grouped into four main categories: system characteristics, system usage and demand, time or cost, and geographic location or area of interest. These categories were derived from the NPRM (*2*). Examples of data applicable to each category are listed below.

- System characteristics: Lane miles, HOV lane miles, capacity, roadway functional class, proportion of system congested, type and location of construction under way, location and duration of incidents;
- System usage and demand: VMT, person miles of travel, average daily traffic (ADT), number of vehicles and persons using HOV lanes, proportion of travel congested or delayed, proportion of persons and vehicles delayed, duration of peak period;
- Time or cost: Person hours and vehicle hours of delay, average speed, peak period speed, average peak and off-peak travel time, proportion of travel time under congestion or delay, parking cost; and
- Geographic location or area of interest: Central city, suburbs, suburban fringe, geographic information system coordinates, specific functional classification.

These four categories formed the initial framework for the data categorization, but since some of the data found did not fit into these categories, three additional categories were identified: land development activity, transit and rail, and miscellaneous. The miscellaneous category consisted of those data that were found to be used only once but did not fit into any other existing category. This category was eventually dropped from the analysis.

REVIEW OF SYSTEMS AND PROGRAMS

Implementing congestion management systems is a new process and the information from the two available congestion management systems was supplemented with that of performance monitoring systems. The four performance monitoring systems reviewed are more broad based than congestion management systems, although congestion management systems can be considered a subset of performance monitoring systems. Six state and regional programs established to address congestion and transportation performance are reviewed: four performance monitoring programs and two congestion management systems.

The congestion management systems evaluated are located in Washington State and in California. The California congestion management requirements are based on state legislation, but the aim of both the state and the federal ISTEA legislation are similar and the data collection efforts are comparable. California congestion management efforts vary by county; particular emphasis was given to the Los Angeles County congestion management program.

Performance monitoring systems measure an agency's or a jurisdiction's effectiveness in achieving established goals. The goals of a performance monitoring system may be related to transportation, land use, or any other measurable aspect of the agency. Of the four performance monitoring systems reviewed, three are on the East Coast (New York, New Jersey, and Maryland) and the one is in Oregon.

Congestion Management

Southwestern Regional Transportation Council

The Southwestern Regional Transportation Council (RTC), located in Clark County in southern Washington State, has developed a recommended congestion management system. The CMS performance evaluation system (or indicators) proposed for RTC focuses on a corridor congestion ratio and a congestion index, which was developed and defined specifically for this RTC CMS. The corridor congestion ratio is the aggregation of three measurements for all links in a transportation corridor: vehicle miles traveled, volume-to-capacity (V/C) ratio, and a VMT-weighted V/C ratio. These measurements are summed to create a corridor congestion ratio and are then grouped into six categories to form congestion indexes. The indexes range from corridor congestion ratios of less than 0.6 for the lowest congestion index to corridor congestion ratios of greater than 1 for the highest congestion index.

The RTC CMS develops performance thresholds. The performance threshold of a corridor is based on the transit and transportation demand management (TDM) priority of the corridor. The performance thresholds help both to define acceptable levels of congestion and to associate congestion with transit and TDM strategies. The transit-TDM priority is a "combination of a corridor's transit, TDM and land use characteristics and reflects the priority given to nontraditional travel modes in the corridor . . . in general, the higher the priority, the higher the performance threshold is set" (*3*). Data collection requirements for the RTC are given in Table 1.

Several aspects of the RTC approach to CMS provide guidance on the types of data useful for congestion monitoring:

- Corridor congestion can be measured through a combination of vehicle miles traveled and V/C ratios;
- Thresholds can be established based on transit and ride-share data that include transit service capacity, transit ridership, and average vehicle occupancy; and
- The choice of using link data or screen-line data can be based on land use (i.e., commercial).

California's Congestion Management Program

The state of California enacted congestion management legislation prior to ISTEA adoption. Only counties with urban area populations of more than 50,000 are required to develop congestion management programs—approximately 32 of the state's counties.

TABLE 1 Southwestern Washington RTC CMS Data Requirements (*3*, Table 5–5)

SCREENLINE INPUTS:
Transit Service Capacity - frequency, capacity per vehicle
Transit Ridership
Average Vehicle Occupancy (AVO)
LINK INPUTS:
Length
Number of Lanes
Capacities --should be reflective of functional classification, signal spacing, truck volumes.
P.M. peak hour traffic volumes (updated annually for monitoring locations)

State Requirements The California Congestion Management Program (CMP) has nine basic requirements. The legislation itself is straightforward and brief, leaving room for local interpretation. Because the California CMPs are implemented on a county basis, these local interpretations vary widely. The nine state requirements are listed below (*4*):

- Form a congestion management agency,
- Identify a CMP system,
- Establish level of service standards,
- Set transit service standards,
- Develop trip reduction and travel demand management programs,
- Perform land-use impact analysis,
- Formulate capital improvement program,
- Monitor conformance with the CMP, and
- Require deficiency plans.

Within these nine requirements, the CMP legislation sets certain minimums. For example, the CMP system is required to consist of at least state routes and principle arterials (although the term *principle arterials* is not defined by the legislation). Level of service (LOS) standards are not to be set below LOS E, unless the facility is currently functioning at LOS F. Transit LOS must include frequency, routing, and coordination of transit service.

Of the nine steps previously listed, the land-use impact analysis includes evaluating impacts of local land-use decisions on the regional transportation system, including estimating the cost of mitigating adverse impacts. The required capital improvement program must maintain or improve LOS and transit service standards, mitigate adverse impacts, and improve air quality. If the LOS drops below the standard, a deficiency plan must be developed that works to improve the deficient roadway segment or improve the overall CMP system performance.

This review of California CMPs indicated that most areas are responding directly to the level of service analysis through facility improvements. Transit-related improvements and TDM mechanisms are addressed, but primarily by showing that the requirements are met because a county has transit or TDM mechanisms.

Los Angeles County CMP The Los Angeles CMP differs from the other California CMPs reviewed. The goal of the Los Angeles CMP is to avoid additional congestion before it occurs, rather than respond to it after the level of service analysis indicates a deficiency.

The Los Angeles CMP is built on the assumption that all new development contributes to system deficiencies (*5,6*). Los Angeles County focuses a debit and credit system related to trip generation rates and person miles traveled. Therefore, new developments accrue debits and mitigation measures accrue credits. Cities in Los Angeles County are provided with guidelines for calculating debits and credits that directly influence their land-use decisions. The debit and credit system is broad enough to guide zoning and building permits but is also detailed enough to provide guidance on specific building criteria, such as providing effective HOV preferential parking.

Performance Monitoring Systems

Performance monitoring systems are broader than congestion management, but the data requirements of each can work in conjunction to obtain the needed information. Four performance monitoring systems were reviewed in conjunction with this paper:

- Middlesex Somerset Mercer (MSM) Regional Council, New Jersey, study of the impact of land-use strategies on suburban mobility;
- Montgomery County, Maryland, adequate public facilities monitoring report;
- Regional Plan Association, New York, working paper on measuring transportation system performance; and
- 1,000 Friends of Oregon, LUTRAQ (Land Use, Transportation, Air Quality) Model for Portland Metropolitan Region.

Performance monitoring systems measure an agency's or a jurisdiction's effectiveness in achieving established goals. The goals may be related to transportation, land use, or any other measurable aspect of the agency. Because performance monitoring systems can address such a wide variety of goals, a full description of each performance monitoring system is inappropriate in this report. Instead, summaries of the data types used in the transportation monitoring are presented.

MSM Regional Council

The MSM Regional Council conducted a study to explore the interaction between suburban land-use trends and regional transportation. The purpose of the process was to determine the effects on regional transportation of high-density, mixed-use centers as alternatives to current land-use trends. The MSM Regional Council in New Jersey uses four indexes—VMT, level of delay, average speed, and number of vehicle trips—to monitor the transportation impacts of three different land use possibilities, called "constructs" (*7*): a transit construct, a short-drive construct, and a walking construct.

Three of the indexes were straightforward: VMT, level of delay, and average speed. These indexes were measured directly for each land-use construct and compared with the base year measurements. The vehicle trips indexes included several criteria:

- Overall office-retail-housing mix,
- Jobs-housing ratio,
- Total employment,
- Design integration,
- Proximity to rail transit,
- Presence of radial bus service,
- Presence of internal bus service,
- Constrained parking supply for commercial uses, and
- Increased residential density.

Montgomery County, Maryland

Montgomery County assesses transportation and land-use capacity annually. The adequacy of public facilities is addressed on the basis of individual geographic policy areas. A threshold level, called a "staging ceiling," may be established for each policy area, expressed as the number of jobs or housing units to road capacity. For each policy area slated for new transportation capacity, the staging ceiling on new jobs and/or housing units is reviewed annually (*7*). The review is based on the following criteria:

- The list of existing approved development proposals;
- Subdivision moratoriums where the ceiling has already been reached;
- The proportion of jobs and households and employees and housing units in the policy area and throughout the county;
- Programmed new capacity estimated to occur within the first 4 years of the county or state capital improvement program;
- Availability of transit in the geographic area;
- Future traffic estimates; and
- The level of service desired for the area.

The county has established service-level thresholds that take into account transit and roadway capacity. The analysis also includes annual estimates of programmed transportation improvements and new developments that are approved but not built.

New York City Metropolitan Area

The New York City metropolitan area has divided the monitoring tools into two categories: highways and transit. The tools for monitoring highways include reduction in speed below the posted limit, delay, number of road travelers affected by reduced speed, loss of time, incidence of commercial vehicles, and vehicle occupancy. Transit monitoring tools include travel time, comfort, and reliability (*7,8*).

LUTRAQ, Portland, Oregon

LUTRAQ represents "a multiyear effort to develop a planning methodology for reducing reliance on the automobile, through a combination of growth management and design policies, transit infrastructure improvements, and travel demand management measures" (*9*). The process uses a forecasting model that works to more effectively link transportation planning with land use. The model uses six monitoring tools: auto ownership, mode share, vehicle trips per household, levels of service, vehicle hours of delay, and vehicle miles traveled.

COMPARISONS

Table 2 gives the types and frequency of the data in use in the programs reviewed. Data in use range from lane miles to parking costs to development demand to transit route and frequency. However, despite the variety of data, the data in use contain some similarities, particularly when summarized by category (Table 3). For example, all but one of the management systems reviewed acquire data on system characteristics. Of the five programs that collect data within system characteristics, all collect capacity information. In fact, three programs (Montgomery County, New York, and LUTRAQ) collect only capacity for system characteristics and no other data for that category.

All six programs collect system usage/demand data, but only three programs (MSM, New York, and LUTRAQ) collect time/cost data. Of these three, all collect data on person and vehicle hours of delay; two have data on average speed and parking costs. New York collects data on peak-period speeds, and LUTRAQ calculates the percentage of travel time congested or delayed.

Most of the programs used data that were land based but that did not fit well with the geographic location/area of interest category. Five of the six monitoring-management programs specifically considered land development activity, such as development density, regardless of the geographic location of the activity, such as whether the development activity is in the city center or the suburban fringe. This indicated a need for categories, and more specific data categories, and the land development activity and transit/rail were developed as additional data categories.

Land development activity was the most frequently used data category of all the data categories, followed by the system usage/demand, time/cost, system characteristics, and transit/rail categories, in that order. The frequency of data types in the land development category is partially dependent on the use of both residential and employment density in the development density.

Capacity was the most frequently used data in the system characteristics category and was found in four of the six programs reviewed. Average daily traffic and vehicle miles of travel were the most common data found in the system usage/demand category.

Person/vehicle hours of delay and average speed/peak-period speed were the most common data types used under the time/cost category. Parking cost, also a part of the time/cost category, was used in two of the six programs reviewed.

While numerous data sources are being used by the systems reviewed, some data sources are *not* being used in the performance monitoring or congestion management systems. The data types that

TABLE 2 Data Type and Frequency Found in Reviewed Programs

CATEGORY	DATA	FREQUENCY
INITIAL CATEGORIES	DERIVED FROM THE NPRM	
System Characteristics	Lane Miles	2
	HOV Lane Miles	2
	Capacity	4
	Roadway Functional Classification	2
	Proportion of System Congested	0
	Location and Duration of Incidents	0
System Usage	Vehicle Miles of Travel	3
	Person Miles of Travel	1
	Average Daily Traffic	5
	Number of Vehicle/Persons Using HOV Lanes	1
	Proportion of Travel Congested/Delayed	1
	Proportion of Persons and Vehicles Delayed	1
	Duration of Peak Period	1
Time/Cost	Person/Vehicle Hours of Delay	3
	Average Speed, Peak Period Speed	3
	Average Peak/Off Peak Travel Time	1
	Proportion of Travel Time Congested or Delayed	1
	Parking Cost	2
Geographic Location	Central City/Suburbs/Suburban Fringe	1
	GIS Coordinates	0
	Specific Functional Classification	0

(continued on next page)

are not being considered under any of the monitoring and management systems are as follows.

- Proportion of system congested,
- Construction under way
- Location and duration of incidents
- Person/vehicle hours traveled
- Average peak/off-peak travel times
- Suburbs and suburban fringe geographic areas
- GIS coordinates
- Specific functional classification.

Of the foregoing data types, construction under way and location and duration of incidents would measure nonrecurring congestion. The *Final Interim Rule* requires monitoring and management of recurring congestion, but nonrecurring congestion is expected to be addressed because incidents often account for much of the congestion in many areas.

TABLE 2 (*continued*)

CATEGORY	DATA	FREQUENCY
ADDITIONAL CATEGORIES	BASED ON DATA FOUND IN USE	
Development Activity	Development Demand	2
	Development Capacity	1
	Development Density	3
	Development Trip Generation	3
	Pedestrian Trip Generation	3
Transit/Rail	Route	3
	Frequency	3
	Capacity	2
	Reliability/Comfort	1
	Park and Ride Lots	1

continued on next page

CONCLUSIONS

Level of service and volume to capacity are common measurements for congestion, and they may be good first steps in developing a congestion management system. However, transportation professionals are not united in their analysis of LOS as an appropriate measure of congestion. Because LOS standards focus on location-specific problems, resolving the congestion problem at that intersection may in fact simply "move" the congestion to another location, while the overall or regional congestion issues are not addressed or resolved.

Moving congestion to outside the city limits came under much discussion in the early and mid 1980s when the San Francisco Bay Area city of Walnut Creek, California, enacted a development mitigation policy linked to LOS standards. Essentially, if the traffic impact analysis for a potential development indicated that the development would require expensive mitigation, the developer would simply move the project outside the city's jurisdiction. However, the traffic problems associated with the development still occurred in the city because people would drive through Walnut Creek to get to the new development. The city had no way to acquire fees to mitigate the impacts of the through traffic.

This problem also happens in reverse; for example, when a city intentionally locates a development where the traffic generated would affect an adjacent jurisdiction's streets more heavily than its own streets. The adjacent jurisdiction would suffer the impacts but would not receive the development revenues. This problem can be at least partially avoided if the management or measurement of congestion occurs at a county or regional level that reduces the potential to shift impacts.

TABLE 3 Frequency of Use of Data Categories

CATEGORY	FREQUENCY
Land Development Activity	15
System Usage/Demand	14
Time/Cost	12
System Characteristics	10
Transit /Rail	10

TABLE 4 Selected Examples of Data Manipulation

KEY DATA		DATA MANIPULATION		NEW DATA TYPE
AVERAGE DAILY TRAFFIC				
Total ADT	x	Total Lane Miles	=	Total VMT
HOV ADT	x	HOV Lanes Miles	=	HOV VMT
General Purpose	x	General Purpose Lane Miles	=	General Purpose VMT
AVERAGE VEHICLE OCCUPANCY				
AVO for All Lanes	x	Total VMT	=	Total Person Miles Traveled
AVO for HOV Only	x	HOV VMT	=	HOV Person Miles Traveled
AVO for General Purposes	x	General Purpose VMT	=	General Purpose Person Miles Traveled
TRAVEL SPEED				
Posted Speed	-	Off Peak Average Period Speeds	=	Off Peak Average Reduction in Speed
Posted Speed	-	Average Peak Period Speeds	=	Peak Period Average Reduction in Speed
Peak Speed Reduction	÷	Total Vehicles Delayed	=	Peak Speed Reduction per Vehicle
Off Peak Speed Reduction	÷	Total Vehicles Delayed	=	Off Peak Speed Reduction per Vehicle
LANE MILES TRAVELED				
Total Lane Miles Traveled	÷	Peak/Off Peak Average Speed Reduction per Vehicle	=	Total Average Peak/Off Peak Delay per Vehicle
General Purpose Lane Miles	÷	Peak & Off Peak Average Speed Reduction per Vehicle	=	General Purpose Average Peak/Off Peak Delay per Vehicle
HOV Lane Miles Traveled	÷	Peak/Off Peak Average Speed Reduction Per Vehicle	=	HOV Average Peak/Off Peak Delay per Vehicle

Additionally, LOS measures of congestion focus more on the needs of the facility than on the needs of the transportation user (*10*). That is, traditional *Highway Capacity Manual* methods of measuring do not address mobility, which is the user's perception of a trip, but look at the facility, which is only one aspect of a trip. Congestion management might be better addressed by a user orientation than a facility orientation. The implication of this suggestion is that the definition of congestion can be determined by the data and the measuring mechanisms. LOS and other forms of measurement, such as a straight V/C ratio, indicate when a road needs to be expanded but reveal less about the user's preferred travel mode.

A congestion management system cannot and should not measure the user's desires, but an ideal congestion management system could address the user's perspective by providing and analyzing data from several modes. For example, a congestion management system can include data on both auto and transit travel, particularly on the single occupancy–high occupancy auto split. By monitoring the changes in single-occupancy auto travel compared with HOV and transit travel, efficient use of transportation facilities and increased mobility can be monitored. This means that vehicle data can be critical in determining the effectiveness or competitiveness of transit or rail. For example, ADT, AVO, and speed data can be used to compare the volume and mobility of SOV travel with transit ridership and mobility.

An effective congestion management system should use data that can be readily collected and analyzed. Ideally, collection should focus on key data sources that can be manipulated to produce other, derived measurements. A few key data types exist that can be manipulated to produce additional informative measurements (see Table 4).

The data recommendations in Table 5 are divided into six main categories, ranging from ADT to transit data to development data.

TABLE 5 Recommended Data for a Congestion Management System for Recurring Congestion

CATEGORY	DATA	DATA SUBSETS
System Characteristics	Lane Miles by Segment	Total Lane Miles by Segment
		General Purpose and HOV Lane Miles by Segment
		Functional Classification
	Capacity	Average Daily Traffic
		General Purpose and HOV ADT
System Usage/Demand	Average Daily Traffic	Type: General Purpose, HOV, and Trucks
		Time: Peak and Off Peak Volumes
	Average Vehicle Occupancy (AVO)	Type: General Purpose and HOV
		Time: Peak and Off Peak
Time/Cost	Speeds/Time	Posted
		Average Peak
		Average Off-Peak
		Duration of Peak Period
	Pricing	Parking Costs
		Congestion Pricing
Transit/Rail		Service - Routes including ridership and frequency
		Reliability - Percent on schedule and percent breakdown
		Transfers - Numbers of
Development Data		Development Type: Residential or Employment
		Development Density
		Trip Generation - including Household Surveys
		Pedestrian Amenities/Design Integration
		Centers Locations
Other Data Sources	Nonmotorized	On/Off Road Bicycle and Pedestrian Routes and Counts

Within each main category, data subsets are recommended. These subsets specifically identify the types of data recommended for collection. Additional derived data can be obtained from each of these data subsets.

Six data types are recommended to provide information for all modes, including nonmotorized. Nonmotorized data were not identified in the programs but were considered important to include all travel modes. Some agencies may only want to focus on a particular mode, while others may wish to compare travel across modes. Collecting data on vehicle, transit, and nonmotorized travel allows comparisons between vehicle travel and transit travel, as well as between vehicle and nonmotorized travel and between transit and nonmotorized. Further, the recommended data types can provide information to both the transportation provider and the transportation user.

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Management System for Transport Infrastructure

ANTTI TALVITIE

No network level management models have been developed for new investments in transportation facilities to improve access, increase capacity, or achieve socially desirable goals. Yet investment takes 40 to 80 percent of the road budget, and its share of other modes is not negligible. Two or three road network design models aimed at this objective have been proposed. A model is described having the dual objective of network design and comprehensive, multimodal transport investment. The proposed model suits the management structure and style of most transport agencies because it is based on hierarchical decision making and considers investment trade-offs between regions, functional classes of roads, most important modes of transport, and other road expenditures. The model incorporates multiple criteria and multiple objectives, and it focuses comprehensively on policy rather than unimportant technical details of demand and supply models. These important attributes are lacking in other available transport investment models, which are either macroscopic or multimodal but not both.

In Figure 1 is the design of the Finnish Highway Administration's road and bridge management system (*1*). It has three parts: development, rehabilitation, and routine maintenance. Development consists of new investments or marked improvements in highway level of service. Rehabilitation means periodic reinvestment and maintenance of existing roads and pavements. Routine maintenance refers to snow and ice removal, care of roadside and service areas and traffic signs and markings, and other minor actions to keep pavements smooth and safe. This three-part division reflects the policy and budget-making practices of most transportation administrations, not only of highway agencies, and corresponds to the time horizon of decisions: development for the long range, rehabilitation for the intermediate range, and routine maintenance for the short range.

There are three administrative decision making levels, shown compactly as rows in Figure 1, in each road program area. The first, the network level, deals with policy and is usually exercised by the central management in the administration or the ministry. The second, the project level, is normally performed by the district office's engineers charged with execution of the policies and deals with design. The third, the program level, lies between the network and project levels and is the joint responsibility of the central administration and the district offices. Its function is to program the actions over years to implement the policies set at the network level—the multiyear road program.

The model discussed in detail in this paper belongs to the upper left hand box in Figure 1. It is designed to help in decisions about how much, in what region, for what mode and service type (national or local), and when new transport investments should be made. These kinds of decisions are strategic long-range choices and may be expensive; attached to comprehensive pricing, tax, and environmental reforms or policies; or otherwise have large impacts on users, the environment, and the national economy. For this reason the decision-support systems for investment strategies must consist of models that are broad in scope.

The approach presented is new. Instead of the traditional link-level transport systems analysis appropriately suited for project-level development decisions, the models chosen are input-output and capital budgeting formulations sometimes used in analyzing government allocation of resources to different industrial sectors of the economy. The discussion that follows is couched in terms of a country, but the model could be applied on a larger scale where the question is in what country or region, for what mode, and on what level (national or local) should transport investments be made.

The system of models described does not replace project planning tools. What is needed by management, and what the present model provides, is the ability to analyze new transport investments, operating subsidies, or comprehensive taxation and pollution controls in large domains or categories and assess the likely benefits and costs of such actions.

GENERAL STRUCTURE OF THE TRANSPORT DEVELOPMENT MANAGEMENT SYSTEM

Requirements

In pavement management systems and maintenance management systems, the logical objective is to minimize the highway agency plus highway user costs, subject to a budget and road condition constraints. Models with such objective function have been implemented (*2,3*). The optimization in these models also solves for the optimal level of service. This is an important characteristic because the agency level-of-service standards may not be optimal but simply engineering conventions. It is essential to preserve this constrained optimization in all the models to allow trade-off of monies between the three domains—development, rehabilitation, maintenance—to gain the useful interpretations of an optimum.

A second required feature of the system is multimodality: highway (including bus), rail, and air. Multimodality, which also implies consideration of both passenger and freight traffic, is necessary because of questions about rail construction in place of highways and busways, and because the value of travel time makes air ever more attractive to long-distance passengers and high-valued freight.

A final requirement is to include all important policy considerations and their interrelationships in a comprehensive manner in a "block" structure, whereby "blocks" of objectives or constraints can be added as knowledge becomes available and new issues emerge.

The questions addressed are where—not which—links should be constructed, for what mode, in what (regional) order and extent,

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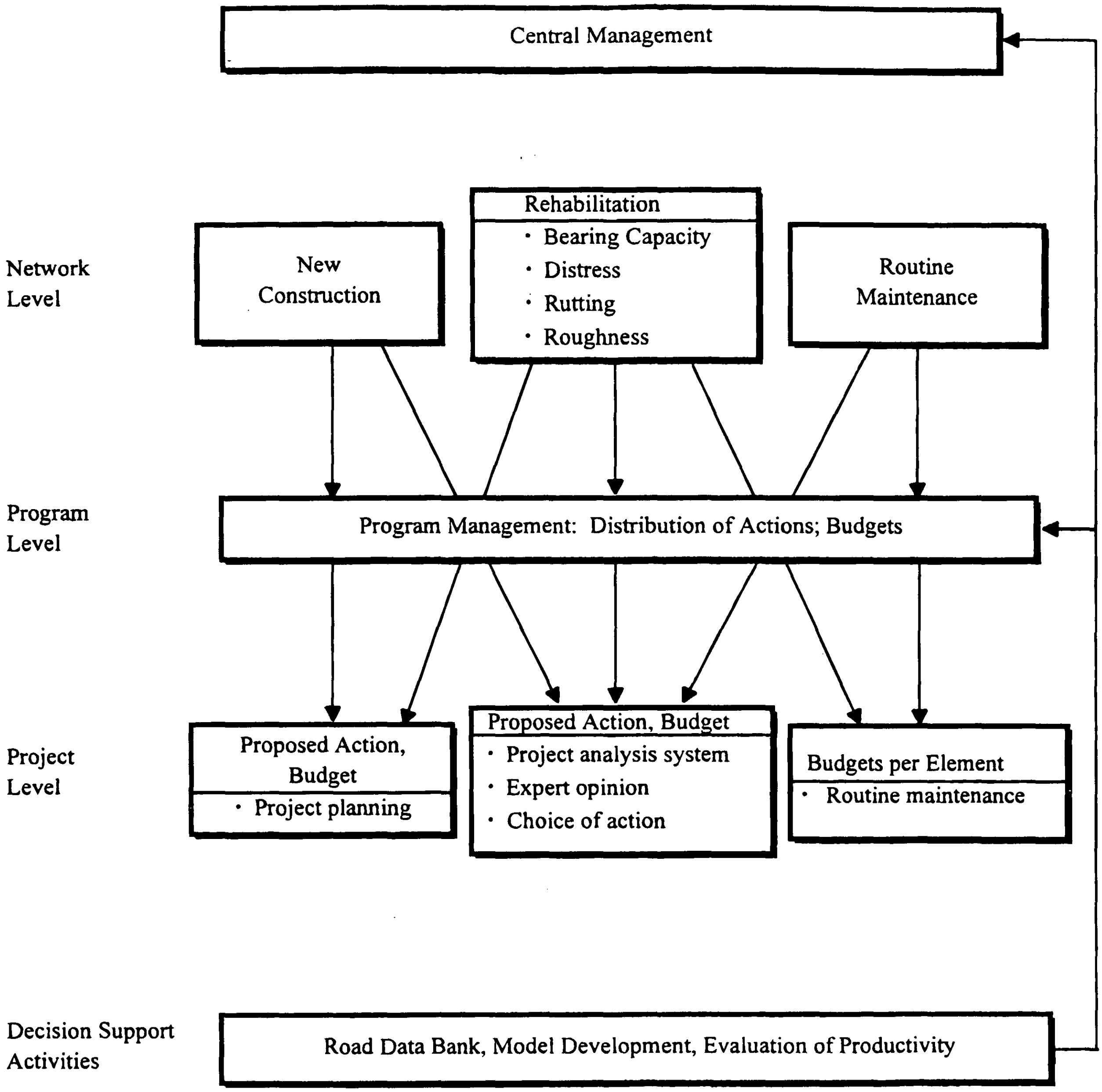

FIGURE 1 Highway agency investment and maintenance models.

when, and whether there should be other conditions (e.g., pricing, subsidy, etc.) attached. Because transport system planning is also driven by social objectives—regional policy, employment policy, environment, taxation, and so forth—their inclusion in the model is necessary. A model system satisfying these requirements is formulated as the constrained minimization of total transportation costs. Figure 2 shows the model framework; it has a comprehensive, block-type structure that can be developed in stages by many actors [see also Morlok et al. (*4*)].

The remainder of this section presents a mathematical representation of the model system, describing most important factors involved. Notation is given in Table 1. It is recognized that every concern is not addressed, but a much larger number of important considerations than are incorporated into the present models are addressed as shown in Figure 3. The transport development management system (DMS) provides a useful and consistent framework for analyzing economic, social, and environmental impacts of all transportation expenditures.

After presenting the model, the policy variables available in the model will be once again reviewed.

Objective Function

The objective function minimizes the fixed facility, operating, user, and pollution costs of transportation, subject to constraints. The minimum cost point is zero: when there is no traffic, no transport facilities are needed. There are three types of fixed facilities: highway, airline, and rail (water can be added, if desired). On each of these fixed facility networks several types of transportation service

Relationships	Common Carrier Vehicle Movements and Capacity	Road Design	Fares and Tolls	Demands	Effectiveness Measure
Minimizing total annual costs	Cost	Cost		Cost	
Subject to					
Technological limitations	Performance	Performance		Flow quality	
Demand functions	Level of service	Level of service	Level of service	Flow quality	
Effectiveness: Profit	Cost	Cost	Revenue	Revenue Cost	Minimum profit
Effectiveness: Capital budget	Cost	Cost			Maximum expenditure
Effectiveness: Accessibility	Level of service	Level of service	Level of service		Accessibility objectives
Effectiveness: Social state	Level of service	Level of service	Level of service		Social state objectives

FIGURE 2 General structure of optimal multimodal network operations model.

TABLE 1 Notation

Sub- or superscripts (lower case letters designating variables):

i = investment; y = rehabilitation; h = routine maintenance
r = region number
k = functional highway class (1=main, 2=regional, 3=local)
t = capital cost type (1=fixed facility, 2=terminal, 3=equipment)
m = fixed facility mode (1=highway, 2=air, 3=rail)
s = service type
for m=1 car, s=1 auto alone, s=2 carpool,
truck s=3 local truck, s=4 regional truck,
bus s=5 local bus s=6 regional bus
for m=2 air, s=1 to/fr Helsinki, s=2 regional, s=3 freight
for m=3 rail, s=1 national, s=2 regional, s=3 freight
e = emission type l = lower bound u = upper bound

Decision Variables and Constants (capital letters)

Q = existing highway capacity - e.g. lane kilometers
C = additional, new highway capacity
K = Q + C
M = existing fixed facility capacity on common carriers (eg.railkm)
N = new fixed facility capacity on common carriers
L = level-of-service attributes (V, P, F, access distance)
F = frequency of service, V = speed of travel, P = price of travel
D = demand, pass/ton/vehicle kilometers (per day or year)
CO= car-ownership
PO= pollutants emitted
E = occupancy (pass/vehicle, tons/vehicle, train)
B = budget constraint

G, T, A = demand generating, distributing, attracting attributes
S = socioeconomic attributes
FC, FT = maximum available flow capacity on common carrier links, terminals
LF= load factor

Parameters and Coefficients (lower case letters defined further by sub- or superscripts)

c = facility, operating, user variable or fixed cost (e.g. FIM/facilitykm per year)
a = pollution cost (FIM/vehicle km)
μ = pollution emission rate (pollutants per vehicle km)

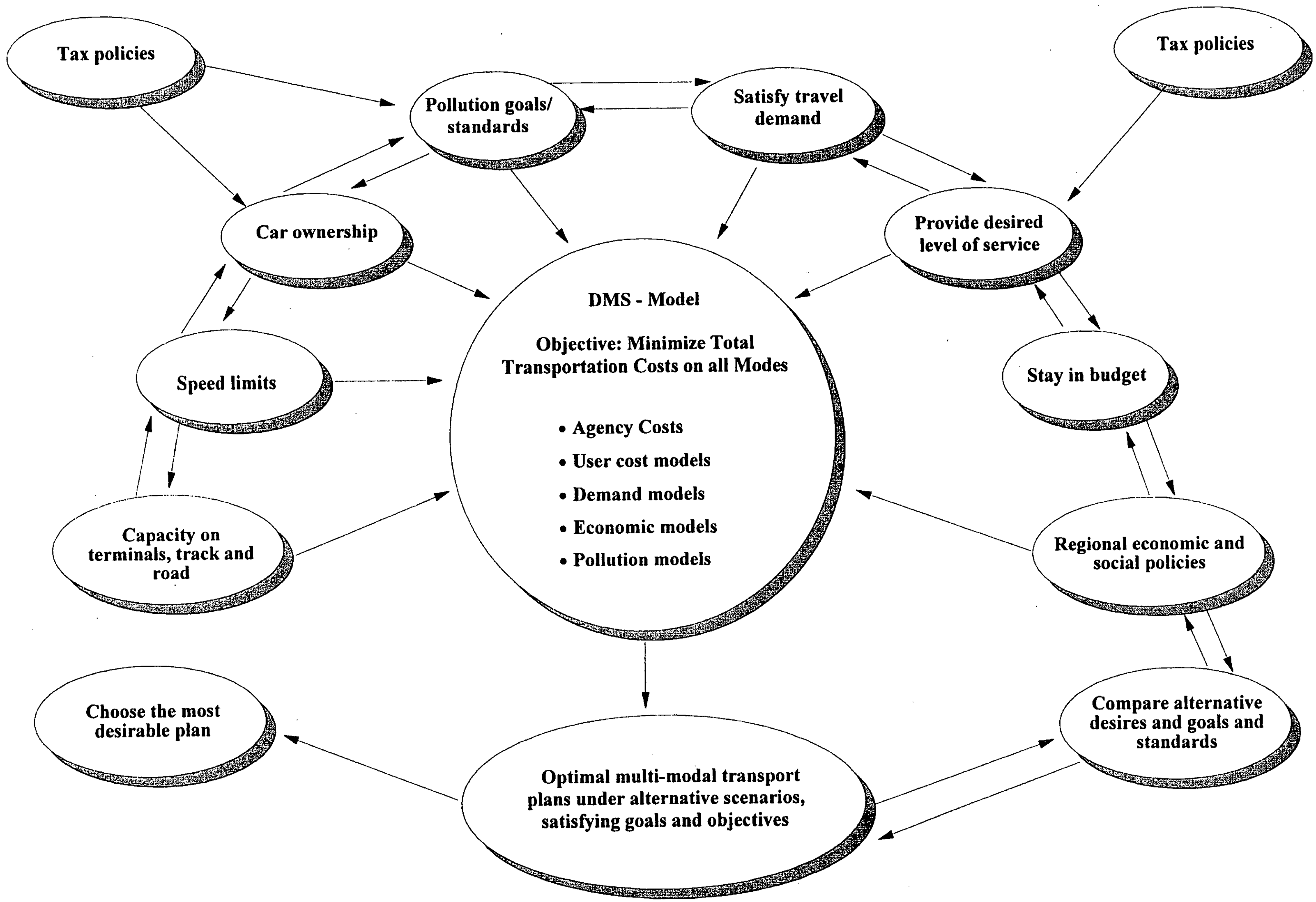

FIGURE 3 Decision-making considerations modeled in DMS.

are provided (e.g., drive alone, carpool, local truck, regional truck, local bus, and regional bus on highways).

The fixed facilities costs of highway consist of three components: capital costs of building new roads or lanes, rehabilitation and periodic maintenance costs of existing roads, and costs of routine maintenance. These costs, and the operating and user costs, are expressed separately for three functional classes: main highways, regional highways, and local roads, each represented in terms of kilometers of lanes and covering all public roads. The operating costs for cars and trucks are calculated as a function of vehicle kilometers of travel, and vehicle size composition. In this way, for instance, an optimal allocation of funding among road classes can be determined (Figure 4).

The size of the network, in terms of lane kilometers by functional class, is one of the decision variables in the model. Thus, the model indicates whether the size of the highway network is too small or large, economically speaking. This is especially important in developing countries, where road expenditures often take a sizable percentage of gross domestic product (GDP). Equally important, the size of the network (by region) can be set as a constraint, that is, the present network will not be abandoned. However, that will have repercussions on the level of service provided on important links. Too large a network will also reduce the budget available for rehabilitation and maintenance and worsen the condition of existing roads.

The fixed facilities costs of the common carrier modes (bus, rail, and air) are also of three kinds: new investment, rehabilitation, and maintenance costs. They can further be broken down into terminal, equipment, and network costs. (It may be expedient to add some of the common carrier cost components together for simplicity if the objective of the model is to focus upon highway development.) The fixed facility costs of the bus mode consist of the terminal costs;

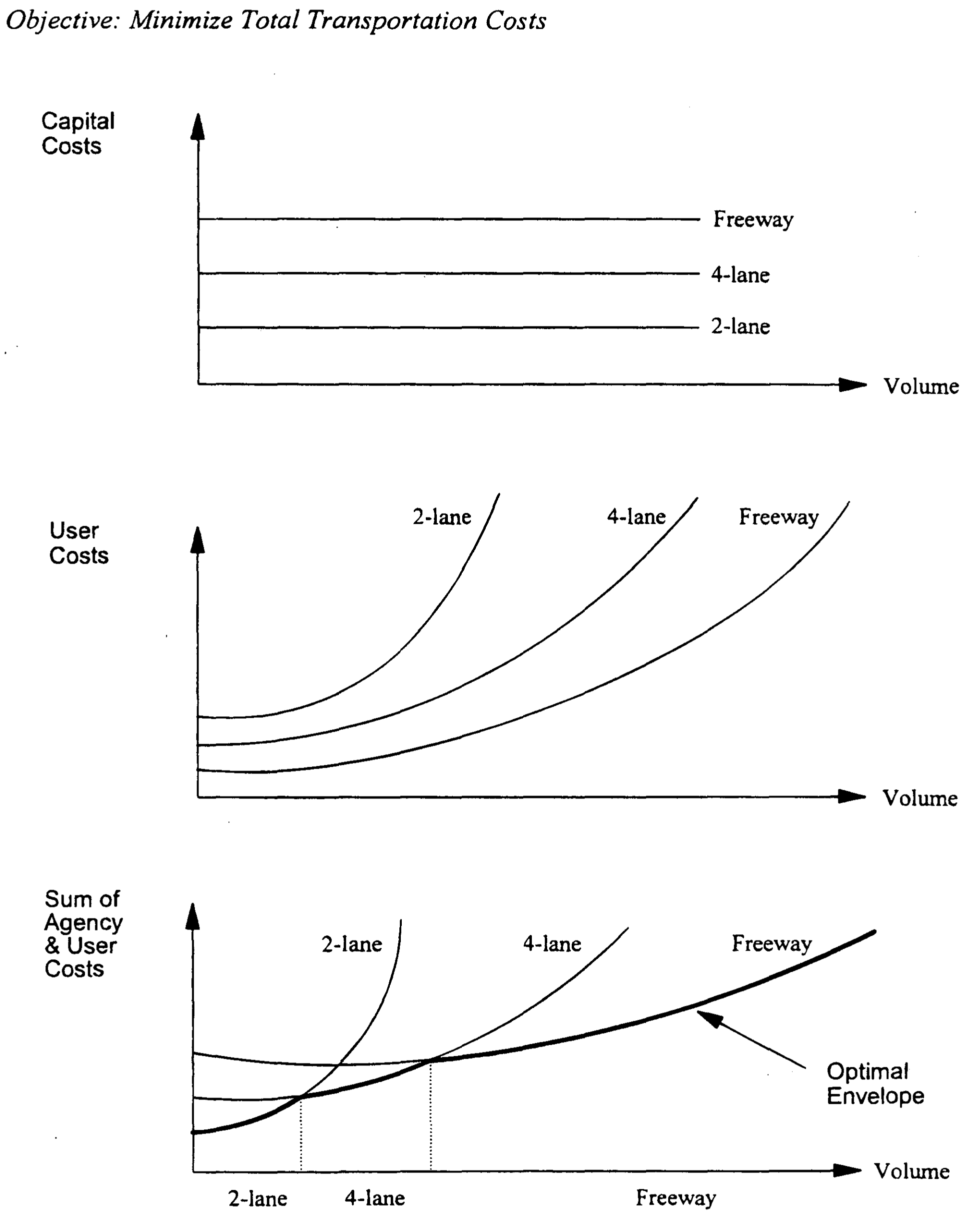

FIGURE 4 One-mode illustration of principle (no budget or other constraints).

there also are equipment costs, which can, but need not, be included as part of the operating costs. The rail network is represented by kilometers of rail lines, terminals, and equipment appropriate to the technology used. For air there are runways, terminals, and equipment.

Operating costs on common carriers with fixed vehicle size (bus, air) and costs on common carriers with variable vehicle size (train, air) can be expressed as a function of route mileage, service type and frequency, and vehicle size, if necessary. The operating costs for bus are proposed to be calculated for two service types: regional and local. Rail has three service types: national, regional, and freight. The air mode also has three service types: national (continental), regional, and freight (national/continental only).

The user costs are calculated as a function of demand. The automobile user costs are, furthermore, divided into two groups: variable (trip) and fixed (capital) costs. Both the variable and the fixed costs can be made to be a function of vehicle size and age distribution. One feature of this division is the ability to model car ownership decisions explicitly, which permits the evaluation of alternative car ownership–car use taxation policies.

If environmental costs (due to pollution, for example) are available, they can be included in the objective function (as done in Table 2) and their effect on the optimal system assessed. The same applies to accidents, which are included in user costs in the present formulation.

To accomplish geographic distribution of costs (and benefits), the country or continent is divided into regions. The number is arbitrary. The number of regions to be used in the model is primarily dependent on the availability of necessary cost information for highway and nonhighway modes and the administrative structure of the country. By using a small number of zones and avoiding link-level representations, the models give a broad-brush representation of the transportation system.

Demand Function Constraints

Travel drives up costs because travel demand must be satisfied. A direct demand model (Table 3), with vehicle or passenger/ton kilometers of travel as the dependent variable, is the forthright alternative for several reasons. First and foremost, flow—vehicle or passenger kilometers of travel rather than trips—is a useful output measure that can be related to resource requirements. Second, models with flow as a dependent variable can include all the typical and important travel demand model attributes in one equation: mode attributes (time, cost, frequency), traffic generating and attracting characteristics (population, employment, industrial structure), and trip distribution and trip length variables (land use pattern, degree of urbanization, activity density, and so forth). The third reason for using passenger/

TABLE 2 Objective Function (Summation over Subscripts)

Highway Fixed Facility Costs, m=1:

$\Sigma^{mi}c_{kr}C_{kr}$	+	investment cost; ${}^{mi}c_{kr}$ unit investment cost of m=1, C_{kr} lanekm of highway of class k in region r
$\Sigma^{my}c_{kr}Q_{kr}$	+	rehab cost; ${}^{my}c_{kr}$ unit rehab cost of m=1, Q_{kr}=lanekm of existing highway; class k, region r
$\Sigma^{mh}c_{kr}K_{kr}$	+	maintenance cost; ${}^{mh}c_{kr}$ unit maintenance cost of m=1, $K_{kr}=C_{kr}+Q_{kr}$, lanekm of highways; class k, region r

Air, and Rail Fixed Facilities Costs, m=2,3:

$\Sigma^{mi}c_{mtr}N_{mtr}$	+	investment cost; ${}^{mi}c_{mtr}$ unit investment cost, N_{mtr} amount of new capital investment of type t (t=1, km; t=2, terminals; t=3 equipment) in region r
$\Sigma^{ym}c_{mtr}{}^{m}M_{mtr}$	+	rehab costs of existing facilities ${}^{m}M_{tr}$; type t, region r
$\Sigma^{hm}c_{mtr}{}^{m}K_{mtr}$	+	maintenance cost; ${}^{hm}c_{tr}$ unit maintenance costs, $K_{mtr}=M_{mtr}+N_{mtr}$, fixed facilities; type t, region r

Note: Formulation allows reduction in capacity, important for rail. May require constraints on Q and M for acceptable solutions.

Auto and Truck Operating Costs, m=1:

$\Sigma^{os}c_{krs}{}^{s}D_{krs}/E^{s}$	+	auto and truck operating costs, m=1, s=1,2,3,4 ${}^{os}c$ operating costs of service type s, ${}^{s}D_{krs}$= travel demand on m=1, s=1,2,3,4; s=1 auto alone, s=2 carpool, s=3 local truck, s=4 regional truck, s=5 local bus, s=6 regional bus; E_s=vehicle occupancy

continued on next page

TABLE 2 *(continued)*

Bus, Air, and Rail Operating Costs, m=1,2,3:

$\Sigma^{oms}c_{msr}{}^{ms}F_{msr}{}^{ms}M_{msr}$	+	common carrier operating costs, m=1 (bus,s=5,6), m=2 (s=1,2,3), m=3 (s=1-3), F=service level (frq/day), M=routekm; service types s; bus: regional, local; air and rail: national, regional, freight

Note:nonlinearity present, FxM. Tentative solution: express the costs additively, c1 marks per departure, c2 marks per vehicle/ train kilometer, and assume that service type accounts for vehicle size, if not then use nonlinear programming. Other possibilities exist also to preserve linearity, for example fix M for each plan and optimize F.

Variable User Costs:

$\Sigma^{ums}c_{krms}{}^{s}D_{krms}$	+	user costs, $^{ums}c_{krs}$ unit user cost by mode and service type

User Fixed (auto-, truck ownership) Costs:

$\Sigma^{ao}c_rCO_r$	+	auto-ownership costs, $^{ao}c_r$ costs of owning a car, AO_r auto-ownership in region r
$\Sigma^{bo}c_rBO_r$	+	truck-ownership costs, $^{bo}c_r$ costs of owning a truck, BO_r truck ownership in region r

This formulation of user costs, as variable and fixed costs, allows the evaluation of alternative auto and truck tax strategies.

Pollution Costs:

$\Sigma^{rms}a_{rkms}D_{rkms}/E_{ms}$	+	modal pollution costs by service type, a unit cost of pollution, D=travel demand; E=vehicle occupancy

ton kilometers of travel as a dependent variable is simplicity. Major advantages are gained because origin-destination flows need not be predicted and the network can be defined in a schematic manner. The demand models themselves will have a simple specification because the generation/attraction variables are combined. Other advantages are that many policy consequences (e.g., pollution) depend on kilometers of travel and trip length, and less on the number of trips.

The justification for this kind of model is threefold: first, most trips are intraregional, not interregional; second, the objective of the model is to guide and help decide (yearly) investments by mode, region, and modal (highway) functional class, not by specific links; and third, the consequences of alternative policies and investments can be modeled and accounted for directly. Direct demand models of the type described above can be entered as constraints: demands must be satisfied consistent with the level of service users are willing to pay for.

Profit and Budget Constraints

The standards of design and level of service must be paid for, and it is be useful to examine the consequences of such standards on goals at an early stage of policy planning. There always exists a scarcity of resources. Profit and budget constraints bring the financial reality into the model (Table 4). These constraints are self-explanatory and require no basic research, only clarification of the costs that must be covered by the revenues from users and, in case of highways, definition of revenues collected. Alternative taxation policies can also be formulated as part of these constraints. A negative profit (that is, a subsidy) can also be formulated as a constraint.

The importance of being able to examine different budget levels and cost recovery levels by mode and their consequences for taxation and user charges and social goals cannot be overemphasized. Using the present models, the budget levels and user charge deliberations are done without knowing what will be done with the monies, how specific policies will affect the usage of transport facilities, and what social impacts they may have. The contrary is also true. Transport planners normally examine their plans without knowing what kind of user charges or subsidies are implied by their proposals, what trade-offs between modes and between programs are presupposed, and so forth. In short, budgets, user charges, and subsidies are considered too late in the transportation planning process.

Accessibility and Technological Constraints

Technological constraints are imposed to help define the set of feasible solutions. They take the form of physical limitations on the

TABLE 3 Travel Demand Models

In generic form the travel demand (model) constraint takes the following form:

$$^{ms}D_r \geq {}^{ms}g(G_r, A, T, S_r, {}^{ms}L_r)$$

where:

$^{ms}D_r$ = demand on mode m, service s, region r passenger/ton/vehicle kilometers

G_r = demand generating variables in r; G(population, employment, industrial structure)

** industrial structure = manufacturing/farming,forestry/service, gvt/ recreation, tourism/energy, constr/

A_r = demand attracting characteristics in r and outside r; the same variables as in G

S_r = socioeconomic attributes of people residing in r; S(Income, Auto-ownership, Family structure, Occupation structure, Age structure, maybe others)

$^{ms}L_r$ = Level-of-service attributes of modes and services available in r; L(in-vehicle travel time/speed, access time/distance, travel price/cost, and frequency)

T_r = Travel demand distributing attributes in r; T(land use)

** land-use pattern = pop/emp density urban/rural; per cent urban; no of cities, area, etc.

Note: It is also possible to formulate a car-ownership model; it would have many of the demand model S variables in the RHS. In that case it would become meaningful to enter car-ownership as a cost in the objective function. (Note: costs of trains and buses are there also; of course, the capital costs of cars could be included in the cars' operating costs in the objective function. The present formulation of the objective function separates the auto user costs into variable and fixed costs; a preferred formulation.)

The car ownership constraint could be of the form:

CO_r ≥ F(Income, Family structure, Occupation structure, Price of cars, Land-use pattern, Level-of-service)

Note: $AO_r = POP*CO_r$. It is advantageous if CO is not equilibrated, but entered directly as a constraint (and as a cost; values of L, if needed, are easiest obtained directly from constraints). The identity equations for auto time equilibrium conditions must be added here. Auto travel time is non-linear but that should cause no trouble.

performance of the transport system or vehicles. All transport modes have a lower bound for travel time because of speed limits or technology limitations; an upper bound can be specified if desired to reflect level-of-service objectives.

These constraints exhibit the standards desired by the travelers or the society. Accessibility can be defined in many ways. The simplest approach is recommended: a combination of level-of-service attributes (door-to-door travel time or speed, frequency of service, and door-to-door cost) afforded by modes in a region by functional class or service type. Accessibility objectives may also be defined for some specific city pairs, or to some important points such as ports, or to the national and regional capitals. Accessibility can be used as an effectiveness measure to evaluate alternative networks.

Pollution objectives can be accounted for by defining upper bounds of vehicle emissions (perhaps together with availability and cost of such vehicles). When pollution cost trade-off analyses are desired, the associated costs must be included in the objective function. If strict pollution standards are assigned to cars, there can be difficulties in modeling the car fleet composition; however, the model system structure imposes no restrictions or difficulties.

A technological constraint is needed for capacity. The capacity of links in a particular functional class must be equal to or greater than the demands on that class; consistency with the travel time constraint must also be maintained. Overall, areawide travel speed-capacity relationships need to be estimated to formulate an area-based equilibrium condition.

Typical technological constraints require only token research for highway modes and for air. The most difficult problem is, perhaps, the condition of the equilibrium on the highway network because it will have to relate travel demand, the vehicle kilometers of travel per area, to capacity, lane kilometers of highway per area. Nonetheless, a reasonable formulation for the equilibrium condition is not likely to be difficult to find. A sample of technological constraints is given in Table 5.

TABLE 4 Budget and Profit Constraints

Budget Constraints

$\Sigma^{i}c_{kr}C_{kr} + \Sigma^{y}c_{kr}Q_{kr}$	$\leq$	Highway Investment Budget (for each r if desired)
$\Sigma^{h}c_{kr}(C+Q)_{kr}$	$\leq$	Highway Maintenance Budget (for each r if desired)
$\Sigma^{mi}c_{rt}{}^{m}N_{rt} + \Sigma^{my}c_{rt}{}^{m}M_{rt}$	$\leq$	Common Carriers' Budget Constraints, m=2,3

$\Sigma^{mos}c_{rsm}{}^{s}F_{rsm}{}^{s}M_{rs} + \Sigma^{mh}c_{rt}{}^{m}M_{rt} - {}^{m}p_{rs}{}^{m}D_{rs}$ (Farebox Revenue)

$\leq$ Common carriers' Operating Subsidy Constraints m=1,2,3 (for each s if desired)

Naturally, all the constraints can be summed up for a grand total transportation budget.

Profit Constraints

$\Sigma^{ms}p_{rk}{}^{ms}D_{rk}$ + subsidy $\geq$ Costs to be covered, even by r and k if desired

Note: The price of travel ${}^{ms}p_{rk}$ (mk/pass.ton.veh.km) may have to be modified into a form p+boarding fee.

Constraints on auto taxation policies, impacting the auto variable and fixed costs can be added here when desired.

Social State Constraints: Preliminary Ideas

Social state constraints, which relate to economic development, can assume a wide variety of interpretations. The inclusion of these constraints depends heavily on what is available. The main idea is to couple network level of service, or investment, in a particular mode and region with social characteristics, such as population growth (decline), employment growth (decline), environmental quality of an area, or profitability of an industry. The problem here is to find and develop such (linear) relationships. For example, if an input-output table is available, preferably by region (but not an interregional one to keep matters simple), impacts of road expenditures on employment by industrial sector and on incomes can be estimated. Input-output relationships are often simple and suffer from uncertainty, but an order of magnitude estimate can nonetheless be obtained. This is an important extension of the traditional transport models in view of the fact that the road administrations are normally asked to take on tasks that are well beyond moving people and goods. These tasks as a rule are related to broad social objectives on poverty, economic development, equity, and the like.

PROBLEMS AND RECOMMENDED SOLUTIONS

The key practical problems requiring resolution are the dynamic short-term/long-term model interface and network aggregation. These two problems are the Achilles' heels in every single mode-optimizing investment model; in DMS the problems are compounded by the existence of many fixed facility modes, many types of transport service on these fixed facility modes, and multiple objectives. The short/long term interface and the network aggregation problems were studied to ascertain that a feasible procedure exists for DMS.

The optimizing model is very straightforward. It minimizes the sum of user and agency costs—the total transport costs—subject to constraints for a given year. The formulation of the model was approached in the following manner: several alternative fixed facilities plans—aggregate networks as defined earlier—are formulated for the time period under consideration. The optimum refers to their optimal capacity and optimal operation in that time period, subject to chosen (or alternative) pricing and taxation policies, service levels, and other constraints. In principle one could optimize the fixed networks for every 5- or 10-year interval and then draw an optimal path through time. There may be other alternatives. The proposed approach necessarily forces consideration of short-term pricing, level of service, and budget policies. This way of solving the time dependent problem is formulated and discussed in the next section.

Spatial network aggregation must be done to keep the model management oriented. One way of doing this is to include only the main highway network, or only its most important parts, as explicit physical links, and to aggregate the rest of the network as a composite link per zone/zone pair. Another alternative, traditional

TABLE 5 Constraints on Accessibility and Technology

Accessibility and Technology

${}^{lm}V_{ksr} \leq {}^{m}V_{ksr} \leq {}^{um}V_{ksr}$;	upper and lower bound on travel speed
${}^{lm}P_{ksr} \leq {}^{m}P_{ksr} \leq {}^{um}P_{ksr}$;	upper and lower bound on travel cost
${}^{lm}F_{sr} \leq {}^{m}F_{sr} \leq {}^{um}F_{sr}$;	upper and lower bound on frequency
$\Sigma^{erm}\mu_{ks}{}^{rm}D_{ks} \leq {}^{erm}PO$; allowed in	pollution constraint, ${}^{erm}PO$=max emissions region r, mode m, ${}^{e}\mu$=emission rate of type e.
$K_{kr} = C_{kr} + Q_{kr}$;	capacity identity, total=new+existing, m=1
$K_{tr} = N_{tr} + M_{kr}$;	capacity identity, total=new+existing, m=2,3
$\Sigma^{mr}D_{ks} \leq \Sigma^{mr}K_{ks} \times {}^{mr}LF_{ks}$;	capacity must be more than demand in each region, LF is a capacity/ equivalency factor. **Note**: K=M for common carriers

On common carriers, of which rail is the only one of concern, the vehicle flow capacity must exceed train frequencies.

$\Sigma^{mr}F_{s} \leq {}^{mr}FC$ ${}^{mr}FC$ is the maximum flow capacity on rail, m=2, region r

Terminal capacity constraint may have to be added here for Helsinki airport; and if rail becomes really popular for it, too.

$\Sigma^{mr}F_{s} \leq {}^{mr}FT$ ${}^{mr}FT$ is the terminal capacity of mode m, air and rail, region r

Additional accessibility constraints may be formulated case by case. For example, lower bound constraints may be desired for Q_{kr} (i.e. highways will not be closed) and $M_{mtr,}$ (bus routes, rail lines or airports will not be closed); constraints may be desired on C_{kr} and N_{mtr} (i.e. certain investments will be made); even some socioeconomic attributes S_r, and demand generating/ attracting attributes G_r and A_r may be constrained from below or above to indicate social or regional policies. Travel demand distributing attributes T_r, may also be constrained from above or below to signal land use controls or regional policies.

network-link/O-D-trip specific formulation, was also examined. Both would have caused unmanageable problems with the demand models, because demand on the main links could not be forecast accurately enough. Making the zone size smaller allows more accurate link-level forecasts, but it once again makes the problem too detailed for efficient management use. Also, meaningful introduction of the multicriteria constraints would have been in jeopardy.

The most promising alternative was mentioned above. The proposal aggregates networks functionally and uses service-specific travel demand models in which the passenger/freight/vehicle kilometers of travel is the dependent variable. This somewhat unconventional approach gives freedom elsewhere, especially in the introduction and formulation of the technological, environmental, and social constraints. An added advantage of the aggregate demand/ supply formulation is the ability to include all traffic in the model.

This type of aggregate formulation serves the decision makers and the top management well. It forces them to think and define the problems in terms of goals and objectives and costs of their achievement. It defers the traditional network-link/trip specific technical problem to that level of planning and administration where it can be appropriately addressed in an established technical paradigm: network (link) alternatives ↔ prediction ↔ participation by affected interests ↔ evaluation ↔ choice ↔ design ↔ implementation.

SHORT-TERM MODEL

The short-term model was investigated to ascertain that such a model can be developed as a component of the DMS, even though no such model need be formulated as part of the DMS. It is well to remember that most long-term transportation planning models are "horizon" models, normally 20 to 25 years into the future. The transportation plan in these long-term models is couched in terms of network, links and link capacities and link volumes, terminals and the like, prices, and so forth exactly as in the short-term models but, truthfully speaking, merely less accurately (but with same precision). The short-term plan and model are only intuitively related to the long-term plan without any specific implementation path. The long-term transportation plan is normally updated about every 5 years, and the short-term and TSM plan every year or every other year. In practice, the situation is often such that the development of the new long-term plan is started when the present has been approved. Thus, the absence of a formal short-term model is not a liability of a long-term multimodal investment model because such models, with a real promise in practical applications, have not in fact been formulated and used.

The DMS model offers an opportunity for integrated short-term–long-term formulation that is pragmatic and realistic. It is recalled that DMS does not specify what links, where and with what capacity, but rather what level of service, on what fixed facility, by what means, and in what approximate geographic area. Important components of uncertainty are thus accounted for or avoided by relaxing the geographic, timing, and modal precision of the long-term plan. Decisions that cannot be made and are not made now are not assumed to have been made.

Mode questions and timing of investments can be more precisely investigated by formulating a short-term DMS model. This is briefly described next. The formulation is a transformation of a network model proposed by Morlok.

DMS is designed to the analysis and design—a synthesis—for several alternative transportation futures. These futures can relate to fixed facilities—investment or abandonment—and terminals, pricing and operating policies, technology, and investment budget. Or, using the notation of this paper (Table 1), the contribution of existing fixed facility and terminal capacities M, Q, FT and FC to costs (new capacities C and N are endogenous in the model); level-of-service attributes F, P and LF (speed V is endogenous); pollution emissions μ; and budgets B can be examined for a horizon year or, for that matter, for any intermediate years.

This approach to long-term planning gives one solution to formulating a short-term model, which, as a bonus, also resolves the nonlinearity problem present in the common carrier part of the (long-term) objective function. The short-term model is most easily described and understood with the aid of Figure 5.

In Figure 5, Targets 1, 2, and *n* represent alternative long-term plans with exogenous specification of Q, M, B, FC, FT, P, and F. (Of these only the first five, existing fixed facility capacities and the budget constraint, are absolutely necessary.) The target plans can be reached several different ways over the 20- to 25-year period. These alternative ways are the potential short-term plans—alternative intermediate fixed facility plans—that can be drafted for various time periods (say, 5, 10, and 15 years from today). Their costs, capacity, level of service, and other consequences can be calculated using the DMS model. Finally, the optimal path to each of the target plans can be computed. This would be the optimal short-term/long-term combination. As shown hypothetically in Figure 5, a long-term plan may have an exclusive optimal development path (e.g., Target 2), or alternative plans may have a partly common optimal development path (e.g., for Targets 1 and *n* the optimal path is the same until 10 years from the present). The communality in opti-

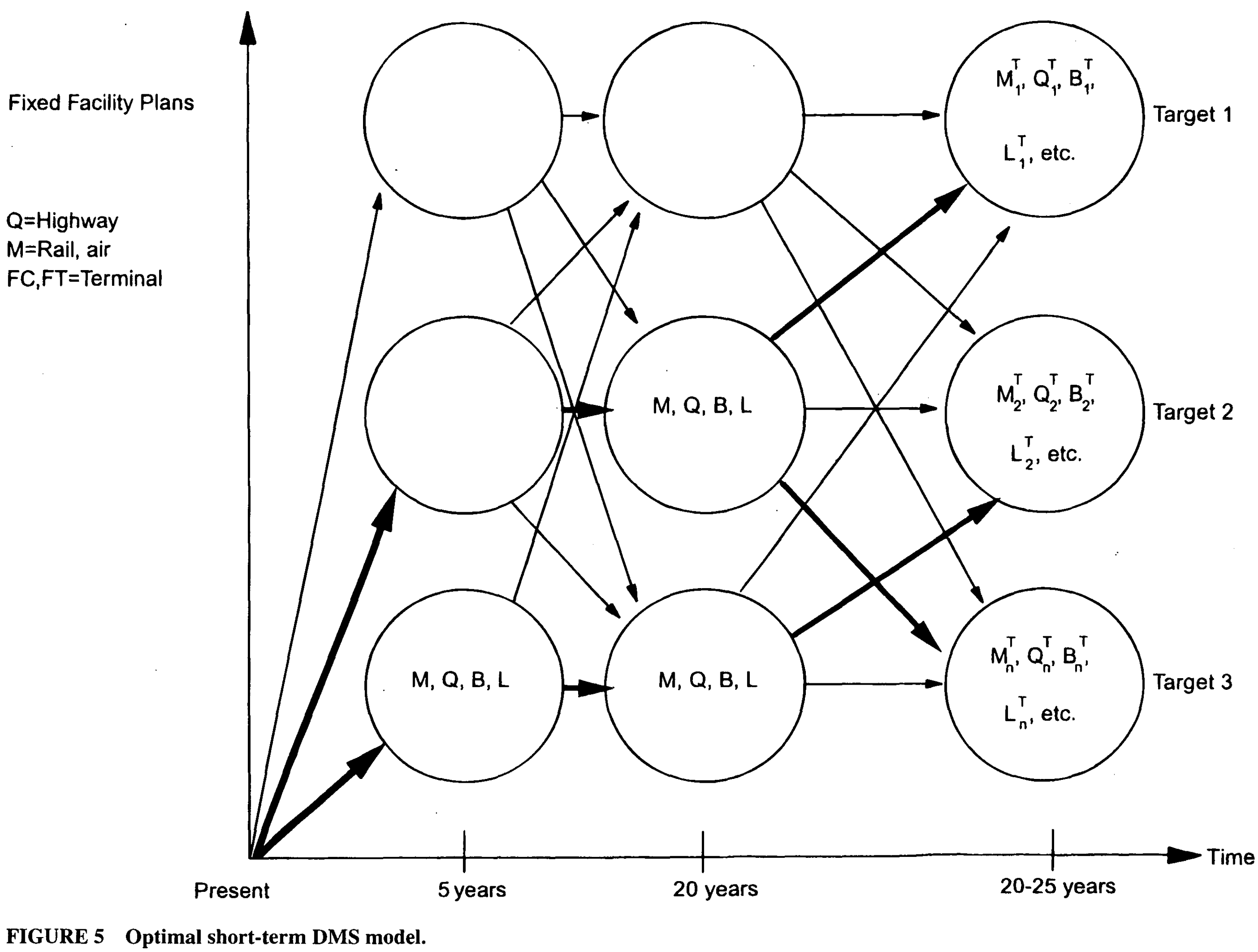

FIGURE 5 Optimal short-term DMS model.

mal paths is an indication of flexibility a plan has in the face of uncertainty; other positive attributes may also be attached to these optimal development paths.

PLANNING PROCESS

All parts of the comprehensive model system lend themselves to a multiplicity of approaches to plan, finance, and implement transportation projects in a variety of organizational settings. Rehabilitation and routine maintenance projects can be identified either by the regional or central organization and carried out either by direct labor or by contract. In a decentralized setting, which is implied and favored, the central administration distributes the resources between programs and regions, suggests the distribution of actions and their budgets, and sets road condition targets for the network. The region chooses the specific links, the specific action to be undertaken and contracts it out, or does it by direct labor. The same applies for routine maintenance and bridges. Of course, it also is possible to "auction" and contract out the entire rehabilitation and routine maintenance program as a whole, or in lots, to private contractors. To define the contracts well, the model system aids the road agency to define the target budget and the target distribution of road condition by volume or functional class that the contractor is expected to deliver.

For investments the situation is more complicated. Again, the function of the central administration is to fix the investment budget (by mode in case of a DOT-type organization) by functional class for highways for each region. Normally there is a national highway plan that is being implemented and there are other links favored or chosen by the road agency. However, recent experience in California and Australia, and elsewhere, suggests that the links or actions chosen by the road agency are not necessarily the ones favored by the private sector. Because only part of the money is earmarked for certain links, the nationally important links, a part is available for choosing those links for which private financing can be leveraged. In this way the public investment can be made to go farther by forming private-public partnerships.

The formation of private-public partnerships and the leveraging of private funds to build transport projects would, of course, lead to a different type of planning process, community participation, and, possibly, land use planning. It would also give the road agency a new role. No doubt, there are other ways in which this type of model system could be used for planning and programming of transportation improvements and for restructuring transport organizations.

CONCLUSIONS

It is emphasized that DMS requires no strict adherence to its recommendations. It merely points out what the cost, environmental, and other consequences are when one path/plan is chosen over others. The strength of DMS is in its simplicity, in the speed and comprehensiveness with which it can analyze the consequences of a multitude of hypotheses about socioeconomics or technology of the future. It also designs an optimal transport plan for alternative future scenarios and permits a timely analysis of a great number of alternative hypotheses or transportation plans without getting bogged down by the details, technical or otherwise.

The DMS formulated in this paper is an innovative tool. The approach presented for transport network design and management is new and well suited for network-level decision making and for transport policy. It is the missing link of the management models and systems developed during the last decade for pavement management and for routine maintenance. DMS is the last piece of the puzzle of Figure 1.

DMS considers new investments in all modes of transport, not only roads. It is a macroscopic management model and does not deal with specific links, terminals, or operating rules, but acts comprehensively at the policy level allowing decentralization of decision making. DMS can incorporate multiple criteria and multiple objectives, in mode specific manner if desired, by relating accessibility and investment to modal demands, to technology and environmental relationships and objectives, to budgets and profits, and to socioeconomic and regional development. Automobile ownership model and taxation policy are examples of social-state relationships already in the model. And as indicated in the text, the model is open to other types of social or regional objectives using, for instance, simple input-output models.

The model also allows assessment of the size of the network by region. In developed and developing countries alike the size of the network is often too large to be economical. Too large a physical plant eats up resources and causes truly important links to be in a poorer condition than required for efficient operation of the system. It is granted that abandonment of lower-level network links is a politically sensitive issue. However, if the true costs and trade-offs of uneconomical links were known, better policies might be devised to achieve similar objectives at a lesser cost.

Finally and very importantly, DMS is integrated with rehabilitation and maintenance actions and their benefits and costs. Because all three components—new investment, rehabilitation/periodic maintenance, and routine maintenance—minimize the sum of user and agency costs by linear optimization of the appropriate objective function, it is possible to perform sensitivity analyses and infer when transfer of funds from one program area to another is warranted in the interest of achieving a global optimum.

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Improving Mobility Through the Congestion Management Program: The Ventura County, California, Experience

CHRISTOPHER STEPHENS AND GINGER GHERARDI

Since 1990, California has required the preparation of a congestion management program (CMP) in urbanized counties. While the requirements of the CMP are not the same as those for the congestion management system (CMS) required through the Intermodal Surface Transportation Efficiency Act, there are many similarities, not the least of which is that both seek the goal of funding and implementing projects and programs based upon a comprehensive and multimodal evaluation of the transportation landscape. Over the past 4 years, Ventura County, California, has used the CMP process to develop and put in place a number of transportation planning and transit service improvement programs. Ventura County's successes may be instructive to others wrestling with the federal CMS requirements.

With the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) in 1991, transportation professionals across the country were introduced to the notion of a congestion management system. Its purpose, as stated in ISTEA, was to "provide for effective management of new and existing facilities through the use of travel demand reduction and operational management strategies."

It is commonly said that the congestion management system was modeled after California's Congestion Management Program (CMP). While this is sometimes debated, ISTEA's recognition and willingness to accept existing programs (the so-called California clause) suggest this idea has merit. Regardless, California's experiences with its Congestion Management Program can provide valuable information to other regions and states as they grapple with their own congestion management systems.

The ensuing discussion summarizes the efforts of Ventura County, with a population of 700,000, to develop, adopt, and implement its CMP. In addition, we describe some of the new programs and services in Ventura County that, while not part of the CMP itself, were initiated as a result of its development and adoption. This paper's focus on the CMP is not meant to suggest this effort occurs in a vacuum. It does not. The CMP is one of many transportation planning and programming efforts and is "synergistically" related to ongoing air quality and land-use planning efforts in Ventura County.

DEVELOPMENT OF THE PROGRAM

In Ventura County, as in most urban counties in California, we have adopted our second CMP and have begun development of our third. Each of these efforts has clearly illustrated the fact that *how* the CMP is developed is almost as important as the policies and programs it contains. This was especially the case with the initial CMP. In 1990, when it was first described to policy makers in Ventura County, the CMP was considered at best another annoying and time-consuming requirement and at worst a threatening loss of local control that should be resisted at every opportunity. Using an active and inclusive CMP development process, the CMP proved to be neither.

For the CMP to be effective, local governments must directly or indirectly implement a number of programs and policies. Thus, they must be made "partners" in the process and allowed to help fashion a CMP that complements and, in some cases, improves local plans and programs. Similarly, transit providers and the air quality agency must also be given the opportunity to help create a CMP that furthers their goals.

All of these interests were accommodated through the creation of three core advisory groups that guided the development of specific portions of the CMP. These working groups were directed toward roadway, land use, and transit and transportation demand management issues. Their participation helped establish the basis for a monitoring and implementation process that was simple, inexpensive, and effective. In short, they dispelled for the policy makers the notion that the CMP was a time-consuming and expensive requirement.

In addition to these working groups, a policy committee was formed that consisted of a combination of elected officials and local government managers, as well as private-sector (business and development) representatives and members of local environmental groups. This committee was instrumental in establishing the goals and objectives of the CMP as well as developing the transportation demand management ordinance requirements (an issue elevated in importance by concurrent air quality planning efforts and the California recession). Perhaps most importantly, this committee provided the CMA board members with a feeling that the direction and objectives of the CMP were reasonable and supported by a broad segment of the community. In essence, the CMP would not compromise local land-use control, nor would it completely open or completely shut the door on development in the county.

Finally, in addition to these committees, the general public was encouraged to participate in the process through a number of special community meetings and presentations before every city council and the county board of supervisors. All of these efforts resulted in the relatively smooth adoption of a CMP drafted and implemented largely by the Ventura County Transportation Commission's small staff, with no perceived contribution to the "bureaucracy."

LEVEL OF SERVICE STANDARDS

While the establishment and monitoring of level of service (LOS) standards were a new (and therefore frightening) prospect for many coun-

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ties, they were well understood in Ventura County. Most local agencies had adopted LOS standards and were familiar with their meaning and use. The central debate was rightly placed on the standard itself and the CMA elected to adopt the statutory minimum—LOS E, or F where it currently existed. While many, if not a majority, of the CMA board members preferred LOS D, the newness of the program and its as yet unknown impacts led them to adopt the statutory minimum.

Once the LOS E policy had been decided upon, the focus switched to establishing the monitoring procedures, including the methodology for calculating LOS. Striking a balance between a desire to monitor the entire system and a desire to control the costs of monitoring, the CMA identified key highway segments, interchanges, and arterial intersections that required monitoring on an annual or biennial basis, depending upon their observed LOS.

Although the majority of the local agencies were already monitoring LOS, they had differing LOS calculation methodologies in place. Virtually all of them were based upon the intersection capacity utilization (ICU) method. This planning-oriented approach (as opposed to an operational one) was well suited to the CMP, where the standards serve primarily as "triggers" to alert the CMA and local agencies to problems requiring additional analysis. To further standardize the methodology, the CMA and local agencies studied the ICU methodology and collected field data to support development of standardized variables (such as lost time, lane capacity, phasing, etc.) to ensure consistent calculations across the county. This methodology eliminated the finger pointing that often occurred between technical staffs of adjacent jurisdictions.

In keeping with the desire for flexibility in the CMP process, the uniform LOS calculation methodology was not mandated in all cases. Local agencies are given the opportunity to submit documentation supporting a change in methodology where they deem it more appropriate. Such documentation is then reviewed by the CMA's standing technical committee.

It is important to note that CMP statute requires a local agency to prepare a deficiency plan when a location within its jurisdiction falls below the adopted LOS standard. The purpose of the plan is to identify the cause of the problem, and implement either the improvements necessary to correct the problem or improvements in system LOS and air quality. In response, the CMA established a policy of local agency cooperation and assignment of costs on a fair-share basis as the guideposts in the development of deficiency plans in the county. Although no deficiency plans have yet been prepared in the county, the cooperative process outlined in the CMP has served as a model for negotiations between local jurisdictions regarding needed transportation improvements and cost distributions.

Ventura County's experience with the CMP LOS standards has, in general, been favorable. When we began the process, the only certainty was that a local jurisdiction would lose its new gas tax funds if it did not meet the adopted standard. Four years later, we have set up a process to direct surface transportation funds to congested areas; we have laid the foundation for a cooperative process for resolving interjurisdictional disputes; and we have developed and used a framework for directing our limited transportation funding toward our most congested locations.

TRANSIT STANDARDS

As was the case for most counties in the state, the development and adoption of transit standards proved to be a difficult and delicate task. This arose largely from—unlike with roadway LOS—the lack of a direct link between the provision of transit services and the new gas tax funds. In California, the two primary funding sources for transit are the Transportation Development Act (TDA) and FTA Section 9 funds. In addition, most counties within the larger metropolitan areas have passed sales tax measures that include substantial funding for transit services. Unfortunately, to date, Ventura County has not passed a sales tax for transportation purposes. As mentioned before, the Ventura County Transportation Commission (VCTC) serves as the county's CMA. In addition to the CMA function, the VCTC is responsible for allocating TDA funds and programming FTA Section 9 as well as STP and congestion mitigation and air quality (CMAQ) improvement funds in the county.

So while there is no direct legal link between the CMP and transit funding, in Ventura County there is a link between the CMA and transit funding. This link has provided the VCTC the opportunity, as the CMA, to establish transit "standards" and then follow through on programs designed to meet them.

The starting point in developing the transit standards for the CMP was a countywide transit services study to identify service needs and develop transit standards for the CMP. Through this effort, the CMA was able to identify a number of services that could be reasonably implemented and that would meet well-documented needs in the county. These services were classified into the CMP categories of routing, frequency, and coordination. As such, the transit standards in Ventura County's CMP were written with the goal of meeting identified needs as opposed to the more traditional service-oriented goal (i.e., maximum load factors, on-time performance, fare box recovery, etc.). Sample CMP standards include the following:

- A 30-minute (peak) and a 60-minute (off-peak) headway on commuter services along the Route 101 corridor;
- Establishment of a centralized transit information center (to provide scheduling and other information for all fixed-route transit providers, both public and private, in the county);
- Creation of a transit operators committee to facilitate better communication and coordination between different transit service providers; and
- Implementation of a countywide transit pass program.

As with the roadway projects mentioned earlier, the implementation of services to meet many of the CMP transit standards benefited from the timing of ISTEA and the newly available STP and CMAQ funds. The CMA was in a position to make funds available for these new services and, to its credit, moved quickly to make these programs a reality. Over the past year alone, the county has seen the initiation of four new commuter and intercity bus services (VISTA), a countywide transit pass, a coordinated transit marketing program, and a number of fare transfer agreements.

In concert, all of these programs have exponentially increased transit's visibility and utility and have for the first time in Ventura County provided a reasonable transit alternative to the automobile. While it may be too strong a statement to say these programs would have never been implemented had it not been for the CMP, it is very fair to say that without the CMP these services would not have become a reality in Ventura County until well into the next century.

LAND USE IMPACT PROGRAM

One of the primary purposes of the CMP was to bring land use and transportation planning closer together. This was to be accomplished in large part through a program to analyze the effect local land use decisions have on the adopted roadway network and transit service standards. The CMA elected to develop a two-tiered process that included a countywide impact analysis program and guidelines for local land use impact programs.

Countywide Program

The CMA is responsible for implementing the countywide land use impact program, which has two elements. The first is an analysis of the cumulative impact of all existing and anticipated development in Ventura County. This analysis is performed at a minimum on a biennial basis as part of the CMP update. The analysis is used to identify and prioritize projects for the capital improvement program portion of the CMP. The information is also used to shape the policies and programs included in the CMP and is passed on to the local agencies so that they may begin to address potential future congestion problems within their communities.

The second element of the program is directed toward the evaluation of large individual projects that might affect the CMP roadway and transit systems. To avoid duplication, this program is limited to evaluation of development projects that were not included in the previous cumulative analysis *and* that generate either 100 additional or 200 new peak-hour trips. The analysis focuses on traffic volumes and distributions as well as potential system impacts. The findings are forwarded to the lead agency for its use as it considers transportation and air quality impacts associated with the project. If the CMA is provided the project information early enough in the process, the CMA's analysis can be used in defining the traffic study work scope.

Local Programs

CMP law in California also requires local adoption and implementation of land use impact programs. In Ventura County, the CMA's determination of consistency and compatibility is based upon the following adopted review criteria:

- Has the program been formally adopted?
- Is the threshold at which the traffic impact assessment is required at least as strict as that in the countywide program?
- Does the program set out procedures for analyzing the impacts of proposed land use on, at a minimum, that portion of the CMP network within the project's impact area?
- If the analysis is based on use of a local traffic model, is the model consistent with the countywide traffic model?
- Does it include or require an estimate of the costs of providing the improvements needed to maintain, at a minimum, the CMP LOS standards on the CMP network?

In Ventura County, the CMP land use impact program requirements have had two direct and very beneficial effects. First, they accelerated if not generated, the effort to develop a countywide traffic model (just recently completed) that will significantly improve traffic impact analyses and further the coordination between transportation, land-use, and air quality planning efforts in Ventura County. And second, they have led local communities to take a *serious* look at impacts beyond their jurisdiction. In addition, the program has had the indirect effect of hastening the development of "reciprocal traffic agreements" between the cities and the county, as well as the possible development of a countywide traffic impact fee.

CONCLUSION

Ventura County's experience with the CMP has been very positive. The policy and technical work done in the area of traffic level of service has been educational for policy makers and has, in concert with the land use impact program, established a framework for assessing intercity transportation impacts and "negotiating" the implementation of mitigation measures. The requirements for transit service standards led directly to a systematic and comprehensive study of transit needs and, ultimately, the selection and implementation of significant service improvements. In concert with other transportation planning programs, the CMP has helped Ventura County toward the goal of funding and implementing projects and programs based upon a multimodal evaluation of the transportation landscape.

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Mobility as a Right

JOHN R. HAMBURG, LARRY BLAIR, AND DAVID ALBRIGHT

Whether the transportation system in a democracy should be designed so that everyone has access to mobility will influence the principles guiding the design and development of the transportation system and which technologies are advanced and to whom they are accessible. Philosophical and political arguments are presented for and against mobility as a right. The question of whether mobility is a right is then addressed from the perspective of 1,600 people randomly surveyed in New Mexico. In addition, a separate, smaller sample was taken of people not commonly involved in transportation system decision making: the physically and mentally challenged, the elderly, the unemployed, and people for whom English is not the primary language. The majority of those surveyed affirmed mobility as a right. Both the random and special surveys identified a relationship between household income, gender, and attitude toward mobility as a right. Mobility is more likely to be considered a right by females and those with lower incomes.

The Declaration of Independence set forth the founding principles of the United States of America. There was a conscious choice to move away from the approach articulated by John Locke, that human rights were related to life, liberty, and the pursuit of property. The choice was to affirm the right of every citizen to life, liberty, and the pursuit of happiness.

The issue addressed in this paper is whether these rights embrace access to mobility. There are times when life is threatened and mobility is required, as in seeking medical care. An issue is whether happiness—as in satisfaction derived from work and recreation—may be meaningfully pursued in the absence of mobility.

Should the transportation system in a democracy be designed so that everyone has access to mobility? The question is both significant and timely.

The answer to whether mobility is a right is significant because it will help guide the design and development of the transportation system; it will influence what technologies are advanced, at what cost, when, and to whom they are accessible; and it will help resolve difficult and conflicting choices in infrastructure investment. How this question is answered will influence provision of services and evaluation of transportation system performance.

The question of whether mobility is a right is also timely. This is a period of change in the transportation sector. The Intermodal Surface Transportation Efficiency Act (ISTEA) refocused mobility as a system involving all modes of transportation. Alternative transportation approaches are encouraged within ISTEA, and in innovative initiatives such as ITS America. Innovative alternatives are being evaluated as elements of an intelligent transportation system. During a period of system change, if mobility is a right, then access to mobility should be a defining element of the transportation system architecture.

This paper begins with a statement of why it is important to articulate principles on which the transportation system is founded. Philosophical and political arguments are presented for and against mobility as a right. The question of whether mobility is a right is then addressed from the perspective of individuals who were randomly surveyed. The results of the random survey are compared with a separate and smaller sample of the population. Recommendation for further research is presented.

IMPORTANCE OF TRANSPORTATION SYSTEM PRINCIPLES

It is imperative to define the principles that founded transportation systems. Principles underlying transportation system architecture address how the system should be designed, how it should operate, and what it should achieve. In the absence of clearly articulated and integrated principles, transportation is reduced to a random collection of modes, and improvements are reduced to uncorrelated installation of new technologies. With explicit transportation principles, transportation can become a coherent system composed of integrated modes. Advances in transportation can then become the coherent incorporation of appropriate technologies that improve performance as a whole.

The clear articulation of transportation system principles is appropriate to the review and assessment of alternative, advanced system architectures. Transportation has increasingly been understood as essential to the national and international economy. New technologies are being introduced that will change how persons, goods, and information are moved. It is important that these technologies are part of a principled system architecture.

Change in transportation is taking place within and among nations. The United States, the European Community, and Japan are redesigning their transportation systems. In the United States, an intelligent transportation system is being developed through the leadership of ITS America. In the European Community, telematics are being implemented formally through DRIVE. Informal groups, such as the European Community Telework and Telematics Forum (ECTF), are exploring telecommunications and transportation. In Japan, diverse groups are involved in advanced transportation. One of these is the Liaison Council for IVHS, which is a consortium of the Japan Traffic Management Technology Association, the Highway Industry Development Organization, and the Association of Electronic Technology for Automobile Traffic and Driving.

Clearly defined principles are needed to guide and direct such national and international change. Principles are needed for movement of goods and information. Among principles associated with the movement of people, one principle should address access to mobility.

TRANSPORTATION SYSTEM PRINCIPLE: MOBILITY AS A RIGHT

The transportation system principle addressed in this paper is whether mobility is a right. In a democracy, this should be consid-

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ered one of the principles on which a transportation system should be designed and developed. There are arguments for and against mobility as a right.

An argument against mobility as a right is that the meaning of a "right" is diluted if all human interests or desires are confused with guaranteed rights. We may want all people to be able to move physically from one site to another, but this is not a right guaranteed to all citizens. Mobility is not necessary for life, liberty, and the pursuit of happiness.

The opposing argument is that mobility is intertwined with rights of life, liberty, and pursuit of happiness. This is experienced by people unable to reach medical care or safe haven, who have restricted or no employment because they cannot reach the workplace, or who have little if any opportunity to enjoy recreational facilities. Mobility is necessary for life, liberty, and the pursuit of happiness.

A second argument against mobility as a right is conflict between increased mobility and the common interest in quality of life and protection of the environment. If all individuals exercised a right to mobility, there would be an increase in vehicle miles traveled (VMT) on the transportation system. Increased VMT consumes energy and contributes to congestion and air pollution. This would suggest that individual mobility should be maintained or reduced, but not increased.

The argument for mobility as a right is that access to mobility does not mean increased vehicle travel. Ensuring access to mobility may be realized by enhancing or expanding nonmotorized travel, light rail, transit, or paratransit services. Access to mobility could increase miles traveled but not necessarily personal motorized vehicles. Importantly, any restrictions on mobility should be equitably addressed to all people, not secured by intentionally withholding or tacitly accepting limited access by a segment of the population.

A third argument against mobility as a right is that the issue should be addressed as access rather than mobility. Access can be provided through other means, including electronic communication. Rights such as the pursuit of happiness do not require spatial mobility. Rather, what is required is access to experience or information.

The argument for mobility as a right is that electronic communication is a choice among modes and does not replace the imperative to provide spatial mobility within the society. There is also a concern that the people without spatial mobility may be those with least access to the information superhighway. Social equity does not occur when some are able to choose spatial mobility and others have a different and perhaps difficult choice made for them.

A fourth argument against mobility as a right is cost. The nation is confronted with difficult economic challenges. We cannot afford to ensure mobility to everyone. If mobility were accepted as a right, there would be an expectation that could not be realized.

The argument for mobility as a right is the unacceptable human and social cost of not providing access to mobility. Lack of mobility reduces employment, and may systematically contribute to geographies of unemployment. Toleration of inequity breeds a social cynicism that rights are afforded only to those who can afford to secure them. Identical access to mobility may be neither economically feasible nor desirable. However, this is not required for acceptance of mobility as a right. Mobility as a right implies commitment to and design for some access to mobility for all.

The arguments for and against mobility as a right represent some of the differences in how people think about this subject. A survey was conducted to better understand perceptions about mobility, and how those perceptions relate to demographic characteristics.

PUBLIC SURVEY: IS MOBILITY A RIGHT?

During the period of 1992–1994, the Alliance for Transportation Research (ATR) developed a model for statewide intermodal planning. ATR is a partnership among the New Mexico State Highway and Transportation Department, Los Alamos National Laboratory, Sandia National Laboratories, the University of New Mexico, and New Mexico State University. The private contractor for this work was Barton-Aschman and Associates, working on behalf of the state of New Mexico and in cooperation with the U.S. Department of Transportation.

Part of the intermodal model was the design and implementation of a statewide conference to involve everyone who uses the transportation system. In addition to traditional participants in transportation conferences, the event coordinators sought and successfully involved the physically and mentally challenged, homeless, unemployed and underemployed, and people whose primary languages were other than English. This diversity of involvement required lengthy preplanning and public interaction.

Public Survey

A survey was conducted to help guide the intermodal conference. The survey identified public attitudes in the state of New Mexico concerning the transportation system. Issues surveyed included adequacy of transit service and reasons people selected transportation modes.

The survey was distributed in September 1993 at the New Mexico State Fair, held in Albuquerque, New Mexico. Surveys were distributed and discussed on shuttle buses serving the fair, and at a fair booth operated by the state transportation agency. Surveys were also conducted on shuttles at a festival in Las Cruces, New Mexico.

There were approximately 1,600 random surveys collected at these sites. The results reflected a broad range of citizens from throughout the state.

There was concern that distribution of the surveys on a shuttle bus might skew the survey results toward the views of transit users. This proved not to be a problem. Reflective of relatively low population density and limited transit operations, 93 percent of the respondents reported they used transit occasionally or not at all. It should be noted that a survey in New Mexico may not be representative of attitudes across the nation as a whole. There is a predominantly rural orientation, combined with diverse and strong cultural identities.

In addition to the random sample, there were approximate 300 surveys distributed to individuals in special-interest groups. It has been noted that there is cultural diversity in New Mexico. Native American and Hispanic organizations were contacted and helped support the survey of special-interest groups. Physically and mentally challenged individuals were particularly of interest in the survey and the conference. The effort to survey these individuals served to identify concerns of citizens who had not previously participated in public meetings or conferences on transportation in the state. Of the 300 special surveys distributed, approximately 150 complete responses were received. Because they were not random, these surveys were not included in the survey summary statistics. A later section of this paper compares the results of the special survey and random survey on the question of mobility as a right.

Survey Response

Each person surveyed was asked if he or she considered mobility a right. The question was worded as follows: Do you believe that the ability to get where you want to go in a reasonable time and for a reasonable cost is or should be a basic right in the same sense as freedom of speech or the pursuit of happiness? Overall, 58.9 percent responded yes, they believed mobility to be a right; 20.8 percent responded no; 13.2 percent were uncertain; and 7.1 percent did not respond.

Excluding surveys without a response, 63.8 percent of the respondents affirm mobility as a right, 22.7 percent deny mobility as a right, and 13.5 percent are uncertain (Table 1). The percentages in Table 1 reveal that the conviction of mobility as a right declines with increasing income. Approximately 72 percent of the people in households having an annual income of less that $15,000 believe that mobility is a right, contrasted with 54 percent for households with incomes in excess of $40,000.

Responses by income and gender were examined. Of the survey respondents, 216 (13.3 percent), did not report household income, and 117 (7.2 percent) did not report gender. There were 1,333 (82.3 percent) respondents who answered income, gender, and whether or not mobility is a right. For the purposes of this comparison, nonresponses and responses of "uncertain" were removed. Of those who made an affirmative or negative response, 73.9 percent believe mobility is a right (Table 2).

For surveys included in Table 2, mobility was considered a right by 84.1 percent of respondents from low-income households. This figure successively dropped to 76.4 percent of respondents from middle-income households, and 61.4 percent of upper-income households.

A comparison of responses to mobility as a right by both income and gender is interesting. Males are slightly more likely to consider mobility a right than females for households making less than $15,000 annually. In these lower-income households, 85.3 percent of males and 83.1 percent of females consider mobility a right.

In middle- and upper-income households, more females than males consider mobility as a right. The difference between male and female responses also increases with income. The difference in response by gender becomes most prominent in higher-income households, for which 56 percent of males and 65.7 percent of females consider mobility a right.

Survey responses by age and gender were also compared. Of the 1,616 surveys collected, 1,501 surveys contained responses to age and mobility as a right. Of these, 951 considered mobility as a right; 214 were uncertain. Overall, excluding the uncertain responses, 73.9 percent consider mobility a right. Women were more likely to consider mobility a right than men: 76.8 percent of women and 68.8 percent of men affirmed mobility as a basic right.

There is no apparent tendency or progression in attitude toward mobility as a right as people age, for either males or females. For all age groups 18 years and older, women are more likely than men to consider mobility a right. The exception is people under the age of 18, where males are more likely than females to consider mobility a right.

Table 3 presents the percentage of respondents who were uncertain whether mobility is a right. These percentages are by age group and gender. Beginning at age 18 or older, as males age they tend to be progressively more certain of whether mobility is a right. Male uncertainty concerning mobility as a right declines from 18.6 percent in the 18–30 age group to 6.9 percent for males over the age of 64. Uncertainty about mobility as a right among women ages 18 and older is clustered between 12 percent and 16 percent.

TABLE 1 Responses by Income

Income Range	Yes (%)	No (%)	Un-Certain (%)	Total (%)
Under $15,000	71.7	13.6	14.7	100
$15,000 to $40,000	65.6	20.3	14.1	100
Over $40,000	54.4	34.1	11.5	100
Total	**63.8**	**22.7**	**13.5**	**100**

Note: Non-responses excluded.

TABLE 2 Responses by Income and Gender

	Male		Female		Total	
Income Range	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
Under $15,000	85.3	14.7	83.1	16.9	84.1	15.9
$15,000 to $40,000	71.0	29.0	79.2	20.8	76.4	23.6
Over $40,000	56.0	44.0	65.7	34.3	61.4	38.6
Total	**68.9**	**31.1**	**76.8**	**23.2**	**73.9**	**26.1**

Comment on the Survey Results

The survey identified a relationship between household income and perception of mobility as a right. The survey indicates that mobility is more likely to be considered a right by lower-income people and females. To the extent that the transportation system design and development process includes representation of diverse income and gender, the system may be expected to reflect the perspective that mobility is a right.

Comparison of the Random and Special Surveys

In addition to the 1,600 random surveys, there was a separate, special survey of 300 individuals. Of these surveys, 159 complete responses were received, tabulated, and summarized. The subset of the general population was composed of the homeless, unemployed and underemployed, people whose primary language is not English, and the physically or mentally challenged. These surveys were facilitated by diverse support groups, including Good Will, Good Shepherd Homeless Shelter, Self-Help for the Hard of Hearing, CASA–Hispanic Protection and Advocacy, American Association of Retired Persons, and the Association for Retarded Citizens.

Of those in the special survey, 64.0 percent believe mobility is a right, and 16.4 percent believe it is not a right. This is similar to the general-population, random survey results.

TABLE 3 Ratio of Responses of Uncertain to Total Responses

Age Range	Male (%)	Female (%)	No Response (%)	Total (%)
Under 18	16.1	24.1	0	20.2
18 to 30	18.6	14.6	0	15.6
31 to 45	12.5	14.9	0	14.0
46 to 64	11.8	12.2	0	11.9
Over 64	6.9	15.3	0	11.1
Unknown	0	15.9	8.1	11.1
Total	**11.6**	**14.7**	**5.6**	**13.2**

As in the random survey, the special survey results are closely coupled with household income. The percentage of people who believe mobility is a right declines as household income increases. Excluding surveys without a response, 79.7 percent of people with annual household incomes of less than $15,000 believe mobility is a right; 59.6 percent with annual incomes between $15,000 and $40,000, and 43.5 percent with incomes over $40,000.

The special survey response by gender and income revealed the same pattern identified in the random survey. At the lowest household income in the special survey, a higher proportion of males than females considers mobility a right: 82.6 percent of males and 72.7 percent of females. In the middle-income group of the special survey, a higher proportion of females (66.7 percent) than males (50 percent) considers mobility a right. Of the highest household income group in the special survey, substantially more females (47.4 percent) than males (20 percent) consider mobility a right.

On the question of mobility as a right, the views represented in the special survey were similar to those of the randomly sampled general population. The special survey results underscore the relationship between household income, gender, and attitude toward mobility as a right.

RECOMMENDATION FOR CONTINUING RESEARCH

The survey in New Mexico suggests a possible reason for the discontinuity of transportation system design and limited service: the people advising and helping design, implement, and evaluate the system may not represent the full population; and the difference in approach to mobility may be different between those represented and those not represented. Inclusive representation in transportation system architecture is a subject recommended for further research.

The survey of New Mexico opinion concerning mobility as a right provides insight into one southwestern state. A national survey should be undertaken to better understand the public perception of mobility as a right.

SUMMARY

It is a time of historic change in transportation. Transportation is moving from conventional separation of modes to an integrated system. Intelligent transportation systems are being designed. Alternative architectures and associated technologies are being proposed.

This paper recommends inclusive teams to design these new transportation systems. These teams should clearly identify the principles on which the systems are based. Beyond system architecture, inclusive teams and clearly established principles should be part of the common daily workings of an advanced transportation system.

The survey results suggest that the principle of mobility as a right should be considered representative of public opinion. The conclusion reached by the authors of this paper is that access to mobility is inextricably related to basic individual rights and should therefore be considered a right in the design and development of our nation's transportation system. This right should be ensured so that all people have access to mobility, and that restrictions on mobility for environmental or other purposes should be as equitably applied as access. This right should be ensured so that alternatives to physical mobility are choices also equitably offered. This right can and should be ensured by public planning processes and infrastructure investment strategies that provide access to mobility for all.

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The Ithaca Model: A Practical Experience in Community-Based Planning

David S. Boyd and Amy G. Gronlund

The Ithaca–Tompkins County Transportation Council (ITCTC) is the metropolitan planning organization (MPO) for the Ithaca, New York urbanized area, designated as a result of the 1990 Census. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and its corresponding regulations dramatically altered the public involvement requirements for the metropolitan transportation planning process. In response to the new requirements, the ITCTC implemented a community-based, strategic, comprehensive planning process to assist in accomplishing its first long-range comprehensive transportation plan under ISTEA. The process used seven citizen volunteer transportation task teams to identify and articulate a community vision for the future of the transportation system. During a 5-month period the ITCTC staff facilitated over 70 task team meetings. The process implemented by the ITCTC and the obstacles encountered in this community-based process are described. Several recommendations for future applications are included. The Ithaca Model is of interest for several reasons. First, ISTEA requires that MPOs undertake a "proactive public involvement process" as part of the metropolitan planning process. Second, ITCTC is a small MPO with extremely limited resources, thus demonstrating that a proactive public involvement process is within the capabilities of nearly every MPO. Third, there are significant direct and indirect benefits to be gained from a public involvement process of this scale. The experience of the ITCTC is valuable to any other agency considering the use of such a process.

Ithaca is one of the principal cities of the scenic Finger Lakes region in upstate New York. It is centrally located in Tompkins County at the southern end of Lake Cayuga, the largest of the Finger Lakes. This area is geographically characterized by acute topography due to the glacial activity that created this Finger Lakes region. The community is best known as an education center, as it is home to Cornell University, Ithaca College, and Tompkins Cortland Community College. These institutions provide important sources of employment, education, and social and cultural opportunities to the residents of Tompkins County and the surrounding counties. Due largely to the influence of the colleges and university, local demographics indicate a relatively high rate of educational attainment in the Ithaca–Tompkins County area (i.e., 1990 Census figures show 41.7 percent of the population aged 25 and older have completed 4 or more years of college). According to the 1990 Census, over 38 percent of the resident workforce is engaged in the educational services sectors. These trends contribute to the relative stability of the local economy (e.g., the unemployment rate in Tompkins County is consistently the lowest in the state). It is likely that there is a correlation between these demographic characteristics and the high level of interest in the activities of government exhibited by the local residents. Local political issues (including decisions regarding future community development) tend to be governed by liberal views and environmentally sensitive convictions. All of this makes an interesting environment in which to perform metropolitan transportation planning activities.

Since the Federal-Aid Highway Act of 1962, the establishment of metropolitan planning organizations (MPOs) has been mandated for every urbanized area with a population over 50,000. The 1990 Census revealed that the Ithaca urbanized area had grown to a population of 50,132. Therefore, in September 1992, the Governor joined with the affected local governments to designate the Ithaca–Tompkins County Transportation Council (ITCTC) as the MPO for the Ithaca–Tompkins County urbanized area. The current metropolitan planning area boundary is contiguous with the boundary of Tompkins County, thus encompassing a one-county planning region with a population of 94,097. As a new MPO, ITCTC has both the benefits and disadvantages of having no history associated with planning activities, programming decisions, or a long-range transportation plan.

MPOs are responsible for conducting a transportation planning process in a "continuing, cooperative, and comprehensive" manner. They provide a direct link between the local, state, and federal transportation agencies and governments. This link facilitates and enhances coordination at the local level and provides direct access to the state's decision-making and funding processes. The result is increased project efficiency and heightened sensitivity to local issues. The MPO also provides an environment that is conducive to public involvement and participation in the transportation decision-making process.

In the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), Congress reemphasized the importance of conducting comprehensive metropolitan transportation planning activities. The joint planning regulations (23 CFR Part 450; 49 CFR Part 613) promulgated by the U.S. Department of Transportation (DOT) provide specific instructions to MPOs regarding the way in which transportation decisions should be made. The regulations specifically emphasize diversity and balance among transportation modes, preservation of existing systems, and increased public involvement in the decision-making process. MPOs are directed to solicit more public involvement than ever before, both from a wider range of publics and at more points in the planning process.

To receive federal planning funds, MPOs must perform specific activities. One of these activities is the development of a long-range transportation plan. This plan must provide a fiscally constrained, 20-year vision of transportation issues facing the region and must be completed and approved by the specific deadlines established in the regulations. As a newly established MPO, ITCTC was faced with the monumental task of simultaneously initiating all aspects of a functioning MPO, including the development of the initial long-range transportation plan. To be sensitive to the disposition of the community and to satisfy the public involvement requirements of ISTEA, ITCTC chose to implement a community-based, strategic,

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comprehensive planning process to facilitate the development of its first long-range transportation plan. The remainder of this paper explores the experience of the ITCTC in developing what is referred to as the Ithaca Model for public involvement.

DEVELOPMENT OF A "PLAN TO PLAN" (*1*)

Community-Based Planning

The Ithaca–Tompkins County metropolitan area is a unique area to upstate New York. As previously discussed, the socioeconomic profile of the residents includes relatively high levels of education and family income, due largely to the strong community ties to its three major academic institutions. As a result, the citizens of the metropolitan area are inclined toward active participation in local planning activities, especially those that have the potential for significant ramifications on the natural and built environments. Historically, the hallmark of transportation decision making has been one of contentious debate and indecision. The last major road construction project was completed in 1968, and only rehabilitation activities and minor geometric improvements have been completed since (and these have not been without controversy). The most recently approved major project has been in the discussion stages since 1946. Given this decision-making climate, it was necessary that the transportation planning process be designed to facilitate broad-based community participation while addressing the strategic issues associated with plan implementation.

A community-based planning process was adopted to accommodate the interests of the community while meeting the needs (i.e., the regulatory requirements) of the MPO. Community-based planning has been defined as "a cooperative planning process in which the planning agency, elected officials and citizens who live in a community work in true partnership to create a vision for their community's future, build consensus in the community for that future and develop specific plans and projects to make that future happen" (*2*). This process was achieved largely through the use of seven transportation task teams combined with other involvement techniques (e.g., public meetings and events). Through this process, citizen volunteers were asked to assist in articulating the spirit and vision of the community and to help identify the transportation issues of vital concern to the populace.

Strategic Comprehensive Approach

Planning efforts are guided by a theoretical framework that establishes certain stages and benchmarks in the development of a plan. Two different frameworks are commonly used. The first—the traditional "rational comprehensive" approach—has the benefit of identifying boundless numbers of issues, developing goals related to those issues, and making decisions based on documented conditions (i.e., data). The downside of such an approach is the "rationality limit"—the point at which we, as humans, are no longer capable of explaining the complex relationships that exist in the urban form. The second approach, referred to as a "strategic" planning technique (3), has its roots in military and business management applications. Strategic planning processes attempt to be implementation oriented by focusing on key issues and the environment in which the decision is to be implemented (external and internal opportunities and threats). In a strategic planning framework, the lack of data as a reasonable course of nondecision is not accepted. The downside to this approach is that by initially constraining the number of issues considered, strategic planning may tend to oversimplify relationships and limit potential solutions.

The objective of the "strategic comprehensive" approach is to combine the strengths of the strategic process with those of a rational comprehensive process. This technique was implemented in the *1986 Comprehensive Plan* for the city of Arlington, Texas (*4*). The result is a process that facilitates the identification of broad-based issues and then quickly focuses on those issues with a strong potential for implementation. ITCTC's strategic comprehensive approach included the following steps: establishing a conceptual framework for the development of the plan, identifying major transportation issues, developing and articulating a community vision, refining and prioritizing the issues, developing strategies that address the highest priorities, examining the strategies to determine their implementation potential, and allowing appropriate time for adoption, implementation, and feedback. Step 1, completion of the conceptual framework, the veritable "plan to plan," was accomplished by *ITCTC* as a prerequisite to the project. This document addressed community participation, outlined the planning process, described the format of the final document, provided the mission statement and general goals and objectives that the plan should strive to accomplish, and presented a schedule for completion of the plan. To complete the remaining steps, ITCTC employed several community-based planning techniques, including the use of seven citizen advisory committees, the transportation task teams.

Transportation Task Teams

In mid-November 1993, ITCTC began the process of creating seven transportation task teams. These task teams were organized based on functional and issue areas: bicycle, pedestrian, infrastructure, mobility, public transportation, intermodal, and environmental. The purpose of these task teams, as stated in the conceptual framework, was to assist ITCTC in developing specific and measurable goals, objectives, strategies, and actions that would address major transportation issues within their respective functional and issue areas. Due to the regulatory deadline for completing the initial plan (December 18, 1994), the task teams were expected to complete their assignment within 6 months. Five to seven citizen members were targeted for each task team to ensure an optimal committee size. To obtain the citizen volunteers, solicitations were sent directly to ITCTC's mailing lists (over 200 people); press releases were distributed to local radio, television, and print media; and general block advertisements were published in the two local newspapers. MPO member contacts with various other civic groups, boards, and commissions were also used. Individuals interested in participating were asked to contact ITCTC by mail or phone and to indicate their area(s) of interest and to identify any special expertise or experiences. ITCTC received a significant response to the solicitation but was still able to assign all volunteers to a task team, and, in most cases, to establish a balance among the opinions represented on each team. The volunteers had a wide variety of backgrounds and consisted of an interesting cross section of the community (homemakers, scientists, activists, schoolteachers, etc.). The membership for the seven task teams was formally approved in January 1994.

It is important to recognize a number of features of the task team initiation process. First, the limited term of commitment (i.e., 6 months) seemed to result in a broader range of participants. For this particular effort, a broader base of participation was viewed by ITCTC as being more important than establishing sustained, long-term advisory committees. Second, while a good cross section of the community was obtained, it was not statistically controlled for any variable (e.g., sex, race, age, physical condition, geographic location of residence, owner-renter status, income, etc.). Third, despite the potential for conflict, the "balance of opinions" was desired to achieve temperate results that would appeal to the total community (i.e., ISTEA deadlines allowed little time for extended community debate). Fourth, the issue of communication between task teams was resolved through liaisons, members of ITCTC's planning committee (i.e., the technical committee of the MPO) assigned to each task team. The resulting structure is analogous to a wheel—the liaisons served as the spokes between the hub (the MPO) and the rim (the task teams and public). Finally, given the limited resources of the MPO (i.e., a staff of two) and the depth of local expertise available, part of the strategy was to tap the brainpower of the community. These features were consciously considered by ITCTC in the development of this process.

THE PROCESS IN ACTION

Task Team Performance

The seven transportation task teams began meeting early in February 1994. They met approximately twice a month for 2-hour meetings. The meetings were scheduled by the task team members to accommodate their personal schedules. While all meetings were open to the public, one of the early complaints was that some meetings were held at inconvenient times (i.e., during regular working hours). In addition, ITCTC staff kept other citizens who expressed interest in the project but did not have the time to be full-fledged task team members informed through frequent mailings and telephone correspondence.

Each task team was asked to select a group leader to keep the meeting process productive and on schedule. In response, some task teams selected a standing chairperson; others rotated responsibilities; another picked a "timekeeper"; and one proceeded without any formal leadership. The ITCTC staff, along with a member of the ITCTC planning committee acting as a liaison, provided technical and administrative support to the task teams. The staff provided agendas and advance materials, action summaries of previous meetings, reading materials, and other information as requested by task team members. While attendance and participation at task team meetings were considered as minimum activities, task team members were encouraged to perform as much additional reading and research as their personal schedules allowed. The overall objective was to provide the task teams with sufficient latitude and the resources necessary (within limits) to reach their own conclusions within the time frame allowed by the ISTEA deadline.

The first objective of each task team was to refine the list of major transportation issues identified at the first public meeting. The task teams then generated mission statements and began to prioritize the major transportation issues that were facing them. In time, the task teams developed goals, objectives, strategies, and action items that were recommended to ITCTC for inclusion in the long-range plan. Over the 5-month period February to June 1994, over 70 task team meetings were held and approximately 6,500 hours of volunteer time were contributed (not counting untold hours spent outside of meetings doing additional reading and research).

Events

Three general public meetings and one transportation "fair" were held throughout the planning process. The transportation fair (EXPO '94) was held on Saturday, May 21, 1994, inside the transit center (bus garage). This event, modeled on a previous event held in September 1993, consisted of a symposium of speakers and over 50 exhibits from private and public organizations. The intent was to provide an informal setting for the public to meet with representatives from the MPO, state DOT, local transit operators, and any of a number of advocacy groups and organizations (e.g., the Sierra Club, the Finger Lakes Police Mountain Bike Association, the Tompkins County Greenway Coalition, New York State Department of Parks, etc.). The local media provided extensive pre- and postevent coverage. As expected, the participants (approximately 300 persons) were very interested in appropriate transportation and other environmental issues. The event provided a positive environment to introduce the MPO and its efforts, increased the public's awareness of the need to plan for the transportation future of the area, and facilitated extensive networking among the advocacy groups and the represented agencies.

The public meetings were scheduled to coincide with the beginning, middle, and end of the task team process. Instead of a traditional (i.e., reactive) public hearing format, these meetings were designed to encourage proactive participation and to promote one-on-one interaction between the general public, the MPO members and staff, and the task team members. All of the public meetings were videotaped for possible use on public-access television (i.e., live broadcast time was not available).

In January 1994, ITCTC kicked off the long-range planning process with its first formal public meeting. The goal of this meeting was to obtain direct input from the public on those transportation issues affecting the metropolitan area. This meeting was held in a *charrette* format in which small breakout groups were used to brainstorm lists of current and future issues. A professional facilitator was hired to ensure that the meeting progressed in a positive and creative manner. The presence of such a facilitator clearly helped to communicate to the participants that they were on neutral ground and helped to ease most of the groups' inhibitions. In an effort to further reduce costs, local planning experts with strong advocacy backgrounds, working under the direction and supervision of the professional facilitator, were recruited to facilitate the breakout groups. The meeting was once again widely publicized through direct mailings, local media contacts, and block advertisements. In addition, large colorful advertisements were placed in all public transit vehicles. The meeting was held in a large room at a centrally located (and accessible) downtown hotel. The meeting drew approximately 50 people. All of the ideas generated that evening were recorded on newsprint and reported by group representatives in a general assembly at the conclusion of the breakout sessions. While the issues were still in rough form, it was evident that considerable overlap and consensus existed on many issues. The final reports and breakout group notes were compiled by the ITCTC staff to form lists of transportation issues affecting the area. These lists provided the first input to the task team efforts.

On July 7, 1994, the second public meeting for the long-range plan was held. The purpose of this meeting was to present publicly the work of the seven transportation task teams and to receive public input on their efforts. Once again, this meeting was widely publicized and was held at the same centrally located venue as was the first meeting. There were approximately 50 participants. The format for this meeting was a plenary workshop in which a representative from each task team gave a brief overview of their work. After the presentations, the participants were asked to visit each of the seven task team booths where copies of the full team reports (containing the task team mission statements, goals and objectives, strategies, and action items), comment sheets, and representatives from the task teams could be found. This format encouraged direct communication between task team members and the public, further personalizing the process. The observation that the task team members seemed proprietary toward their reports was a good indication that there was confidence that the community-based process was indeed working.

Following the second meeting, a written comment period was extended until August 1, 1994, to give the participants ample opportunity to review and comment on the task team reports. However, due to the severe time constraints imposed by the ISTEA deadline, it was not possible to reconvene the task teams to allow them to fully review the comments and modify their work. Instead, the task of considering the comments fell to the ITCTC staff. Minor corrections and revisions were incorporated into the task team reports, where appropriate. In cases where substantial revision to a task team report was suggested, the comment was not incorporated, although it was preserved for future consideration.

A third public meeting was held on October 12, 1994, to present the draft *2015 Long-Range Transportation Plan* and to receive public comment. This session was held in a town meeting format in which the ITCTC staff presented a brief overview of the draft plan followed by a question-and-answer period. The meeting concluded by offering the podium to anyone wishing to comment to the audience. This meeting fell within a voluntary 45-day public comment period established by ITCTC. Comments received at this meeting and during the comment period were considered in the final draft of the *2015 Long-Range Plan.* Approximately 25 people attended this third meeting.

These events were intended to be low cost and provide an environment conducive to high levels of participation. The transportation fair cost the MPO about $250 (for table rental and printing). The site was free and the cost of promotion was shared with other organizations. One innovative feature of this event was the inclusion of commercial vendors (primarily bicycle dealers and outdoor outfitters) who were invited to exhibit their wares for a small fee (no on-site sales were allowed). This further reduced the costs to the public organizations and helped link the business community to the planning process. The meetings cost about $600 each (room rental and refreshments $200, block advertisements $300, and miscellaneous printing and postage $100) with an additional $150 for the professional facilitator for the first meeting. Attendance at these events, while not overwhelming, was significant. Also important was the level of participation (which should be considered as distinct from attendance), which was considerable. In summary, the total cost for these meetings was approximately $2,200. (Note: these costs do not include printing costs associated with the reproduction of the draft *Long-Range Plan* or the task team reports.)

CONCLUSIONS

Positive Impacts

Essentially the Ithaca Model was a success. A long-range plan was developed that reflected the interests and spirit of the community and was approved without significant opposition. The model, while labor intensive for a small staff, afforded a "proactive public involvement process that provides complete information, timely public notice, full public access to key decisions, and supports early and continuing involvement of the public" (*5*). The direct benefits of such involvement included (a) reduced project cost by tapping the expertise and experiences of the community brainpower; (b) assistance to the MPO in prioritizing future planning and project efforts by identifying areas of clear community consensus or conflict; and (c) the development and articulation of a shared community vision for the future of the transportation system. The indirect benefits of such involvement included (a) increased public knowledge about the relationships between the transportation system and the community fabric; (b) enhanced public understanding of the ISTEA metropolitan planning process and its requirements; and (c) the potential to minimize later delays in project implementation due to public opposition based on a lack of early involvement.

In particular, the task team work was invaluable to the development of the *2015 Long-Range Plan.* The task team goals and objectives were incorporated directly, and the work of the task teams was very influential in determining the policies and recommendations that are set forth in the plan. On a more abstract plane, it is important to recognize that the discussions at the task team level permeate the entire plan, providing a foundation based truly on grassroots input and efforts.

Obstacles Encountered

In general, community-based planning is not without its pitfalls. ITCTC has discovered that working directly with diverse publics presents many significant challenges. Four general obstacle areas, which proved to be a source of significant stress on the process, are discussed below.

Public Participation

The term "public participation" is deceivingly complicated. Participation has traditionally been measured by the number of surveys completed, number of people who attended meetings, and so forth. A more appropriate definition is offered by Sherry R. Arnstein. Arnstein's definition focuses on the redistribution of decision-making power. Arnstein states, "It is the redistribution of power that enables the have-not citizens, presently excluded from the political and economic processes, to be deliberately included in the future. It is the strategy by which the have-nots join in determining how information is shared, goals and policies are set, tax resources are allocated, programs are operated and benefits like contracts and patronage are parceled out. In short, it is the means by which they can induce significant social reform which enables them to share in the benefits of the affluent society" (*6*). While Arnstein's definition is based largely on the social program debates of the time period, in the view of the authors the concept of power sharing accurately describes the intent of the ISTEA regulations. As it is relatively easy to define or measure "participation," it is more difficult to define the "public."

The current transportation planning literature likes to use terms such as "customers," "constituents," "clients," or "stakeholders." While there are differences among these terms, for the purposes of this paper the differences are largely semantic. There are two facets to the obstacle under discussion. The first is the issue of inclusiveness, which is discussed in detail later in this paper. The second relates to interest-group influence and opinion dominance. It has been said that people who go to meetings rule the world and any time you get two or more people to agree on something, you have created an interest group. Since the community-based process and the Ithaca Model rely heavily on meetings, there are some inherent biases in the process. For instance, a person's attendance at meetings is often based on a number of factors, such as the availability of time (often a question of personal economics) or access to transportation. In essence, the more meetings one can attend, the more one's opinion will be heard—and possibly affirmed. When a well-organized interest group is consistently present at meetings, it is possible that its convictions may begin to carry disproportionate influence on the outcome of the process. While these opinions may be both valid and valuable, it must be recognized that they may not represent the views of the general population. Amplification of this imbalance through a participatory process, such as community-based planning, could result in a blurred community vision. However, the tempering of this influence may lead to claims of "foul" by the interest group. Thus, one of the obstacles encountered in the Ithaca Model was how best to keep interest-group influence and general-public sentiment in a balanced and rational perspective.

Attendance Versus Participation

The second obstacle was the dichotomy between attendance and participation. In simple terms, high levels of attendance do not automatically equate to meaningful involvement in the planning process. Personalities and group dynamics play a large role in the level of meaningful participation in any public forum. Since the Ithaca Model relies on the breadth (and balance) of opinions among the task team members, the presence of a strong personality often inhibited the level of input from more subdued personalities.

Task Team Conflict Resolution

Conflicts occurred both within task teams (internal-internal) and between task teams (internal-external). The emergence of conflict was not entirely unexpected, especially considering the diverse nature of the functional and issue areas and the wide range of interests represented by the task team membership. However, the negative impacts of these conflicts (e.g., discontent among members, disenchantment with the viability of the planning process, and loss of significant time to irreconcilable debate) were not foreseen. The internal-internal conflicts were generally easier to reconcile. While they consumed much time, the discussions, which served to facilitate the exchange of information and ideas, were generally valuable to the outcome. More troublesome were the internal-external conflicts between the task teams. Sometimes these conflicts were large and rooted in base philosophical differences (e.g., prodevelopment versus antigrowth), while at other times the conflicts were small and detail oriented (e.g., on-street parking as a traffic-calming device versus on-street parking as a hazard to bicyclists). In the end, the time and resource constraints facing ITCTC simply prohibited total conflict resolution at this time. It is intended that these types of conflicts can be resolved through future planning efforts and activities or on a case-by-case, project-by-project basis.

Power Redistribution

Perhaps the most complex obstacle was the issue of power redistribution. "There is a critical difference between going through the empty ritual of participation and having the real power needed to affect the outcome of the process" (6). Although the role of the task teams was clearly identified in the *Long-Range Plan Conceptual Framework* as being advisory in nature, the extent to which a true partnership was formed between the MPO (i.e., the decision makers) and the task teams (i.e., the public) was questioned by a few people. While this question is valid and deserves further contemplation, the insinuation was that the process represented a sophisticated form of co-optation. The issue seemed to be one of "control" and has two specific aspects: the level of influence the task teams had over the final *Long-Range Plan* document and the impacts the task teams would have over future project implementation. The simple answer to these questions is that the task teams, through their efforts to articulate the community vision through their final reports, essentially established the agenda for the plan and for future implementation efforts. This represents a genuine form of real, although indirect, power necessary to affect the outcome of the process.

Improving the Process

"The idea of citizen participation is a little like eating spinach: no one is against it because it is good for you" (6). The Ithaca Model provided an effective process for articulating the broader community vision and for identifying public concerns; however, the authors have identified several areas that should be addressed in the next application of the process.

Public Participation on Task Teams

Defining "the public" is a difficult task. One of the principal issues is how the public should be defined for the planning process—should it be a statistically correct sample of the population or should it strive to include traditionally underserved populations? The answer to both is yes, but for different reasons. In the Ithaca Model, the task team membership did not present a statistically significant sample of the population, thus reliability of the community vision could be questioned. Given additional time and financial resources, the task team and public meeting processes should be supplemented with focus groups and scientifically designed surveys of the general population.

Obtaining the participation of underserved populations can be extremely difficult. In simplistic terms, these groups generally face more pressing issues than participating in an exercise to think about the future; they are engaged in a struggle with the present. The doctrines of advocacy planning emphasize that planners should seek to assist those least able to assist themselves. Thus, one of the arguments favoring a disproportionate effort to involve the underserved is based on professional ethics. While ITCTC's task team membership represented a wide variety of backgrounds, the adequacy of participation from minorities, disabled persons, and various income groups could also be questioned. ITCTC's efforts to solicit task team members from these underserved groups could be described as relatively unsuccessful. Given additional time and resources, enhanced outreach efforts to these groups should be undertaken. For example, more community leaders (e.g., church leaders, neighborhood groups, etc.) could be identified and personally contacted to encourage them to get their constituents involved. Meetings could be located in areas more convenient to these populations. Special transportation or even child-care services could also be arranged.

Organization and Structure of Task Teams

The experimental component in the Ithaca Model was the extreme level of independence and latitude granted to the task teams. In essence, each task team was given an assignment and asked to work to develop a means to accomplish its objective. Some of the task teams did very well, quickly organizing themselves and beginning work. Others spent considerable time getting organized, trying to determine their leadership structure, or, in some cases, even attempting to redefine their original assignments. One of the clear lessons was that the organization and structure of the task teams should be carefully orchestrated prior to commencing the process. Unless unlimited time is available to conduct the process, there seems to be little benefit in allowing these types of committees to define themselves. Therefore, it is recommended that the roles and responsibilities of committees and their members, as opposed to a general mission statement, be clearly defined and communicated to the participants in the form of ground rules prior to starting the project.

Leadership

One of the biggest problems seemed to be the lack of leadership necessary to keep the task teams focused and on schedule. Several options could be explored for future efforts. First, chairpersons for each committee could be selected and appointed by the MPO. While this may seem heavy handed, it ensures that a person with appropriate leadership skills will be steering the committee's efforts. Second, it was necessary for the ITCTC staff to identify and initiate group dynamics and decision-facilitating techniques in order to jump-start some of the task teams. In general, the staff was unprepared for the level of chaos that existed within some of the task teams. The second alternative would be to provide additional, specialized training in group dynamics, conflict resolution, and decision-making techniques to the staff as part of the preparations for future efforts. An alternative, if resources were available, would be to use professional facilitators. Third, an innovative alternative is to create a group of citizen facilitators. For example, the Texas Bicycle Coalition (TBC) started Project MPO as a means of training its advocates to play a proactive role in the ISTEA metropolitan transportation planning process. By training its advocates to function within the MPO environment, the TBC was able to effectively influence MPO decisions in its favor. MPOs might consider how a similar program could work from the MPO's perspective. Training and educating local citizens to become facilitators, or "MPO Ambassadors," could prove to be useful for public meetings, advisory committees, or for other public presentations (e.g., civic group meetings). This type of program would both empower citizens with the tools they need to participate effectively and equally in the MPO planning process and help create an informed citizenry.

Achieving Consensus

Decision making within the task teams was not always easy. While ITCTC attempted to balance competing interests within each task team, on more than one occasion, the result was heated debate and conflict. The process seemed especially susceptible to breakdown when the task teams began to evaluate strategies for implementation potential. While many of these situations could be resolved by a more definitive leadership structure, most are a reflection of the lack of detailed, localized data. While it was always intended that the initial ITCTC plan would be policy oriented (as opposed to a physical plan) and would establish the direction for future planning and data collection efforts, the lack of data hindered conflict resolution. It is hoped that future efforts will have the benefit of the types of data that are generally available from established MPOs (e.g., travel demand forecasts, local surveys, detailed cost and resource estimates, etc.); however, since there will always be cases where data are not readily available, an alternative method should be considered. One possible solution is offered. When significant debate seems imminent, those items could be assigned to the staff. The staff would then develop the specific proposals (including contingency alternatives) based on the initial committee input (i.e., goals and objectives), the available data and information, and its own knowledge and expertise. Thus, instead of trying to "design a camel by committee" or belaboring wordsmithing, committee members would be asked to react to specific recommendations. This should result in a more efficient use of committee time (although more difficult for the limited staff).

Summary

The authors believe that, as a result of the high level of meaningful public involvement accomplished through the community-based planning process, the final ITCTC planning document accurately captures the spirit and vision of the broader community. However, this is not to say that no resistance to the final product remains. One of the clear lessons is that it is not possible, nor advisable to attempt to satisfy the desires of all of the members of "the public." Those who undertake community-based activities must understand that irreconcilable conflicts may emerge, but that the knowledge of those conflicts is in itself valuable.

The lessons learned by ITCTC and presented in the Ithaca Model are directly transferable to other MPOs and planning efforts. In simple terms, if a new MPO with a staff of two can undertake and benefit from this type of process, even in a highly dynamic sociopolitical climate, then anyone should be able to do likewise.

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Developing a Customer Focus in the Statewide Transportation Planning Process

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In the spirit of the Intermodal Surface Transportation Efficiency Act, the Colorado Department of Transportation in association with the University of Colorado at Denver Graduate School of Business Administration developed an innovative process for obtaining increased public input into the statewide transportation planning process. The university conducted a series of citizen focus groups in each of Colorado's 15 transportation planning regions. The purpose of these gatherings was to meet with those who participated in a telephone survey conducted earlier in the year and explore significant survey findings in greater detail. Significant findings of the focus group proceedings are summarized with emphasis on key issues of public policy discovered in the focus groups. Conclusions about the usefulness of postsurvey focus groups are also presented with an emphasis on the value they were found to provide in evaluation of survey results and preparation of focused response plans.

In the spirit of the Intermodal Surface Transportation Efficiency Act (ISTEA), the Colorado Department of Transportation (DOT) in association with the University of Colorado at Denver Graduate School of Business Administration developed an innovative process for obtaining increased public input into the statewide transportation planning process. The first phase of this information-gathering effort consisted of a telephone survey of households and transportation officials in the state. In early 1994, the university sponsored a survey of over 2,000 Colorado households and 120 transportation officials to define the major transportation issues concerning citizens of the state.

In the second phase of the project, the university conducted a series of focus group meetings in each of the state's 15 transportation planning regions. Separate focus groups were held with citizens, elected and appointed transportation officials, representatives of the business community, and representatives of the elderly and the disabled. The purpose of these gatherings was to meet with those who participated in the telephone survey and explore significant findings in greater detail. By using the informal focus group setting, survey respondents explained their answers to the telephone survey more fully. This information enabled decision makers to better understand the public's feelings and priorities on transportation issues.

This report presents a summary of the responses of citizen focus groups in all 15 Colorado transportation planning regions. It also evaluates the usefulness of postsurvey focus groups to validate survey results and to explore survey results in greater detail. The report is divided into sections that describe the methodology of the focus group process, a description of answers to each of the focus group questions, and conclusions about information gathered in the focus groups and the usefulness of postsurvey focus groups as a research tool.

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METHODOLOGY

Background

A focus group is a meeting of a small group of individuals in an informal setting to discuss a specific set of issues. The group typically comprises 8 to 12 individuals who are invited to talk openly about a specific topic. The interactive nature of the discussion generates many spontaneous comments. From these, a great deal of insight can be gained concerning public views on the topic. Focus groups are often used to obtain qualitative information to better understand the issues associated with a research question and to help develop a formal questionnaire to obtain quantitative information.

A unique research approach is to conduct focus groups after obtaining quantitative information from a survey. Postsurvey focus groups are conducted to explore the possible reasons for the answers in the surveys and to better understand the quantitative results. They aim to provide a context and evaluation of the survey responses.

Venues

Focus groups were held in each of the 15 state transportation planning regions:

- Pikes Peak (Colorado Springs)
- Denver Metro
- North Front Range (Ft. Collins)
- Pueblo Area
- Grand Junction
- Eastern (Akron)
- Southwest (Las Animas)
- San Luis Valley (Alamosa)
- Gunnison Valley (Montrose)
- Southwest (Durango)
- Intermountain (Glenwood Spgs)
- Northwest (Steamboat)
- Upper Front Range (Ft. Morgan)
- Central Front Range (Canon City)
- South Central (Trinidad)

Focus Group Implementation

Consistent with the aim of providing a qualitative context for the quantitative results of the telephone survey, the university contacted people who participated in the survey of Colorado households. In each of the state's planning regions, individuals were invited to participate in a meeting with their fellow citizens to discuss transportation issues. The purpose of the meeting was to provide context and explore responses to the telephone survey.

Typically, the meetings lasted from 1½ to 2 hours and were attended by 8 to 12 individuals who resided in the transportation planning region. The questions for the focus groups were derived from the responses to the statewide household survey. They covered topics including mass transit, ratings of quality, system satisfaction, air quality, funding priorities, taxation and funding allocation, carpooling, and decision-making input. Examples of the focus group questions are included at the end of this report.

At the meeting, focus group participants were presented with regional survey results on these and other topics, and asked if they agreed or disagreed with the regional results. The members of the group were then asked to explain the regional responses and whether these responses seemed significantly different from what they would have expected. The purpose of these questions was to determine if the survey responses were valid and to discover *why* residents from a given region placed more emphasis on one issue over another.

Analysis

The meetings were tape-recorded and videotaped to provide a clear record of the proceedings and to aid in future analysis. Because of the subjective nature of analyzing the focus group proceedings and extracting important qualitative information, each meeting was evaluated and summarized by separate individuals, in an iterative process, to ensure interrater reliability.

Each regional focus group was viewed by at least three members of the research team. The recording was first viewed by each evaluator, who then developed a list of key issues brought up in the meeting. From this list, a summary report of the meeting was prepared. After preparing the regional summary report, each reviewer evaluated the summary of the other team members. The group met to review the findings and to reconcile any discrepancies in the individual summaries. From this, a single regional summary was synthesized.

By using this multiple review process, the group was able to ensure interrater reliability and significantly reduce the chance that any one researcher would arbitrarily skew significant findings and present an inaccurate summary of the focus group. The same multistep process was used in preparing the statewide summary of focus group findings.

SUMMARY OF STATEWIDE RESPONSES

Highways Versus Mass Transit

Throughout the state, responses were much more in favor of spending to improve and maintain existing roads than to build new roads. With the exception of bypasses in towns like Montrose and Ft. Collins, the participants did not perceive a need for new roads. They believed available highway dollars should be used to maintain or upgrade the existing system. The benefits provided by new roads were not viewed as justifying their cost or the money taken away from other activities. Citizens wanted the state to focus its efforts on providing the best possible maintenance of the existing system, and to consider new roads only in very specific instances.

When faced with the choice of mass transit or new roads, the participants opted for mass transit in approximately the same ratio as the statewide survey. However, support for mass transit did vary by region. In areas such as Trinidad, Durango, Alamosa, Montrose, Akron, and Canon City, the support for mass transit was very low. People in these areas did not see the potential benefits of a transit system and believed the region was too widespread to make effective use of transit resources. Pueblo was another area where respondents did not indicate support of a mass transit system because the city's transportation problems were viewed as not being bad enough to warrant the necessary investment.

On the other hand, in major urban areas such as Denver, Colorado Springs, Ft. Collins, and to a lesser degree Grand Junction, there was strong support for improving the mass transit systems. The primary reason for the public support in these areas was to alleviate perceived congestion and pollution problems. Concerns about air quality were central to the support for mass transit in most of these areas. In Denver, residents did not want to see air pollution get any worse. In other areas, particularly Colorado Springs and Ft. Collins, residents did not perceive a severe air quality problem at this time but were concerned air pollution would worsen as the area grew.

Grand Junction was an area where support for mass transit was mixed. Concern was expressed that the elderly and disabled did not have adequate access around town. There was also concern about mounting congestion problems and increased air pollution in the area. Still, these concerns were not strong enough to gain a consensus for significantly increasing the level of public transportation offered in the area.

Smaller cities that indicated moderate support for mass transit were Steamboat Springs and Glenwood Springs. Mass transit was viewed as a way to improve the heavy traffic conditions on Highway 82 from Glenwood to Aspen and to improve connections from Steamboat to Craig. Such mass transit systems were typically viewed as being rail based, however, the high cost of building and operating such systems was not given a great deal of consideration in the discussions.

In major towns along the Front Range, there was support for an intercity rail-based mass transit system that could be used to move people along the entire Front Range corridor. Interest in such a rail link was particularly strong among the respondents from Colorado Springs, who saw the need for improved public transportation links to the Denver area. This interest stretched as far south as Trinidad and as far north as Ft. Collins.

There was some interest in heavy rail solutions to the ski areas—the "ski train" concept. Some of the regions on the Western Slope, which generally refers to the areas of Colorado west of the Continental Divide, saw rail solutions helping tourism and providing local transportation. However, there was little interest in supporting these issues with additional taxes. In Steamboat Springs, little approval was expressed concerning the development of a very specialized mass transit, such as a light rail system between the town and Craig, a transit solution for Route 82 between Glenwood Springs and Aspen, and bus transportation or park and ride for commuters between Montrose and Telluride.

The citizen interviews also pointed out several areas where the public has a low level of understanding of mass transportation issues. The first misunderstanding concerned the use of different rail technologies. Typically, all proposed rail projects were referred to as "light rail." Our interviews indicated that light rail could mean a monorail system, a trolley car system, an intercity high-speed rail, or a subway system. There was very little understanding among the public about the most appropriate use of these alternate systems.

The second major misconception was the true construction and operating costs of any rail-based mass transit systems. There was a perception that due to their efficiency, these systems were not very expensive. In some cases, the perception was that rail is less expensive than buses. In very few cases did members of the public understand the level of subsidization of any rail transit system in the country. It was believed fares alone could support the operation of rail mass transit in the major metro areas of the state.

In all the focus groups, the participants had a difficult time not discussing improving and widening the highways. Even after stressing a forced choice between new roads and mass transit, the longest any group went without mentioning improving or widening the existing highways was halfway through the discussion. Pothole repair was the strongest issue identified by the participants. Most had anecdotal evidence of the absolute need for improvement of a highway, road, or other existing facility. Some of the most noticeable problem areas, such as Route 82 from Glenwood Springs to Aspen and Route 50 between Grand Junction and Montrose, were so infamous they were brought up in focus groups outside of their own regions.

The improvement issue went farther than just improving roads. The participants viewed reducing air pollution, improving safety, and prolonging the life of their vehicles as also being important. The bicyclists, of which there were quite a few in the western regions, viewed the widening of the highways as contributing directly to the quality of their sport. Bikers and nonbikers alike viewed highway widening as a strong safety issue. Many of the participants also viewed narrower highways without bike lanes as very bad for the tourist industry, especially since certain areas of Colorado promote biking as a tourist attraction.

Future Vision of Transportation System

There was strong statewide concern about future congestion, air quality deterioration, and decline in quality of life due to increases in population. Although the concerns were voiced differently and the solutions were unique to particular regions, the fear was the same; transportation problems will get worse. One frequently used expression was the transportation system would be "a mess" in the future.

The more pessimistic views on the future state of the transportation system were based on two perceptions. The first perception dealt with increasing congestion problems from the rapid growth of the state. The participants believed these congestion problems would tax the capacity of the existing system and cause roadways to deteriorate and lead to increased maintenance problems. There was also a strong concern that air pollution would significantly worsen as congestion levels rise.

Participants from the Western Slope (areas of Colorado west of the Continental Divide) saw significant growth coming from land development and an influx of tourists establishing second homes. They foresaw substantial growth in the retiree population leading to transportation problems for the elderly or disabled, especially in outlying areas where the cost of land is still low. These groups also saw a substantial growth in immigrants from disadvantaged countries who will work in lower-paying service positions.

The Front Range, especially from Colorado Springs to Ft. Collins, saw continued rapid growth with increased congestion and deteriorating air quality as the main problem for the future. Most of the focus groups called for improvements in mass transit as a means for alleviating these problems. There was significant support for some type of rail or light rail along the Front Range for both convenience and congestion reduction. These areas were far more supportive of carpool incentives, carpool lanes, and park-and-ride solutions than the rest of the state.

The south central, eastern, and southeastern regions did not appear to believe growth and congestion would be as significant in their regions. They believed their transportation problems required immediate attention, rather than planning.

In areas such as Ft. Collins, Denver, and Colorado Springs, these concerns were also tied to a desire to keep air pollution from getting worse as the area grew and congestion increased. For that reason, these participants were strongly committed to developing workable mass transit alternatives that would reduce the need for using automobiles in daily travel. The public believed the increased use of alternative fuels should be encouraged to mitigate future air pollution problems.

In more rural areas such as Montrose and Durango, the primary concern was to ensure that highways are expanded sufficiently to handle increased traffic flow, and that bypasses are built to divert increased commercial traffic away from town centers. A similar concern about building a bypass to alleviate downtown traffic congestion was expressed in the Ft. Collins area.

Future concerns were also expressed in areas that rely on tourism. In places like Durango, there was a concern that highly congested and unsafe roads would make travelers less willing to choose Colorado as a tourist destination. In these areas there was a strong belief that the highways must be able to safely accommodate the increased number of tourists visiting the state by car.

The second perception that created pessimism among the participants was a lack of trust in public officials. Many areas believed state officials were not properly planning to meet the needs of the future. The view was that officials should be preparing for future growth in population and road congestion. The public also expressed the belief that by adequately preparing, government could reduce the cost of developing and building the transportation infrastructure needed 5 to 10 years in the future.

Overall, there were many suggestions for improving the transportation system in the future. There were many recommendations for promoting the use of alternative power sources, such as liquid natural gas, propane, and electricity, for automobiles and mass transportation. Additionally, several regions called for more research into better means of transportation, such as lighter and more efficient cars to use alternative fuels. Railcar carriers for small commuter vehicles were another suggestion. Several suggestions were made to promote the use of bicycles in the commuter system. These included improving highways and bike paths to accommodate bicycle commuters and incorporating facilities for bike storage on buses and trains.

System Quality

Each focus group was asked to review and comment on the system satisfaction results of their regional survey. In the telephone survey, residents were asked to rate the quality of items such as snow removal, parking, road conditions, planning and design, and convenience. The overall agreement of focus group members with the ranking of important items from the survey was remarkable. Discussions of system quality tended to center on four major topics: repair and maintenance, congestion, air quality, and safety.

Reactions throughout the state were in favor of better repair and maintenance of the existing road system. The focus group's opinion was that proper, initial repairs would reduce the overall cost of the repairs. Rather than making less expensive, shorter-lasting improvements to the roads, participants indicated they preferred quality repairs, even if it increased short-term costs. The opinions on repair and maintenance were particularly strong in the more rural areas of the state, such as Akron and Trinidad, where users tend to do more long-distant driving.

Another issue concerned the way increased congestion affects the transportation system. Increased congestion was the primary reason for calls to improve and widen existing highways in the state. Congestion was viewed as contributing to both safety and air pollution problems. Such concerns about increasing congestion were expressed in both the major urban areas and smaller towns experiencing growth problems, such as Durango.

Safety was also identified as a specific problem. While tied to maintenance problems and increasing congestion on the highways, safety was raised several times as a specific concern to system users. Participants in the Glenwood Springs area pointed to the problems on Highway 82 in particular. In this and other areas, it was suggested the state return to mandatory vehicle inspections to ensure vehicles were safe to operate.

Air quality was raised as a concern in the discussions of system quality. A complete description of responses on this topic is provided in the section on air quality.

On a positive note, there was widespread approval throughout the state concerning the quality of snow removal. With few individual exceptions, focus groups in all the regions indicated the state does a good job of clearing snow from the roads quickly and efficiently. The only concern raised was the contribution of sanding to air pollution problems.

Overall System Satisfaction

Opinions on satisfaction ranged from areas like Ft. Collins, where citizens said they were generally satisfied with the transportation system, to areas like Colorado Springs, where citizens indicated dissatisfaction. Generally, respondents indicated an overall satisfaction, exclusive of a few specific items.

In the larger urban areas, such as Denver, Colorado Springs, and Grand Junction, feelings of dissatisfaction centered on inadequate mass transportation options. Focus groups believed mass transit should be more convenient and available for day-to-day trips and not just useful for commuters. Participants noted the inconvenience of the bus system, especially outside of regular commuter times. They stated increasing frequency of service and expanding routes would be necessary to enable riders to give up their cars. The safety of riders waiting for buses was also a concern for commuters in these areas.

Members of the Colorado Springs focus group implied their mass transit system did not meet expectations and needed to be upgraded significantly. Upgrades included expanding operating hours, increasing the number and frequency of buses, and making the system more convenient for the elderly and disabled.

As previously discussed, congestion, safety concerns, and poor air quality were also identified as factors leading to feelings of dissatisfaction with the transportation system.

In rural and isolated areas, like Durango, Trinidad, and Akron, dissatisfaction often stemmed from beliefs of being overlooked by state officials and being the last place of concern for transportation planners. Lack of proximity to the Denver area definitely contributed to perceptions that rural problems were not taken seriously by state officials.

Other factors that created some levels of dissatisfaction were repair and maintenance, safety, and planning and design. The country and county roads were perceived as being poorly maintained. The poor quality of repair work was believed to cause costly, inconvenient, and frustrating multiple repairs to the same roads. These maintenance problems also contributed to safety and congestion problems, particularly along I-25, from Colorado Springs to Trinidad. Planning and design were singled out several times as needing significant improvement in Montrose, Trinidad, and Pueblo. Officials were criticized for poor planning and for not correcting safety and convenience problems.

Air Quality

Air quality was a significant issue in the focus group discussions. It was linked to concerns about growth, congestion, and support for mass transit. While the level of concern over air quality varied across the state, the issue was raised to some degree in all regions. The participants' judgment of air quality throughout the state varied, depending on whether they resided in urban or rural population centers. In the principal metropolitan areas, there was a strong belief that air quality should not deteriorate.

In the Denver area, there was concern mass transit should be more fully developed to prevent local air quality from deteriorating further. In areas such as Ft. Collins and Colorado Springs, the perception was air quality was not a current problem. However, group members were very concerned that as their area grows, air quality would deteriorate significantly and problems similar to those in Denver would develop. These concerns were so strong that people in these areas said they would support increasing taxes to pay for air quality programs or to improve mass transit to keep additional cars off the roads.

Similar concerns were expressed about the increase in air pollution in the Grand Junction area. However, the perceptions of Grand Junction's current air quality problems were not sufficiently alarming for residents to strongly support mass transit development. Focus group members also expressed optimism that alternative fuels would be an effective means of reducing vehicle emissions.

Residents of some rural regions also cited air quality as a specific concern. In Glenwood Springs and Steamboat Springs, focus group members expressed strong concerns that air quality would deteriorate as increased traffic and congestion occurred with growth and increased tourism. Air pollution was viewed as increasing in these regions, so there was support for increased taxes to pay for air quality improvements or emission inspection programs. However, these areas did not support increases in statewide taxes to fund pollution control programs for Denver or the other major urban areas of the state. Support was shown for a statewide emission inspection program to keep high-polluting vehicles off the roads.

A few rural areas, like Canon City, Durango, and Alamosa, did not view air pollution as a particular problem. Citizens in these areas did not see a deterioration in air quality, so they were suspicious of pollution control programs that would be funded with new taxes. Residents of these areas were also concerned that more strict emissions standards would negatively affect commerce and commercial trucking in their regions.

Several of the groups believed that a reinstitution of the safety inspection program, whether supported by user fees, conducted by the state, or some combination, would be good for improving air quality and safety. In some areas, respondents mentioned increasing or reforming emission standards as a means of improving air quality, but did not address implementation issues. They also viewed research and promotion of alternative fuels as a means of reducing pollution.

Spending Priorities

In the telephone survey, respondents were asked if they would like to see spending increase or decrease for various items. These items included spending for pothole repair, transportation-disadvantaged persons, improvement of existing roads, new roads, timing of stoplights, courtesy patrols, expanded bus service, sanding and snow removal, electronic highway signs, and carpool lanes. The result was a list of items, often six or more, the respondents believed needed increased funding.

Focus group discussions showed, however, that when presented with a ranking of items for receiving increased funding, residents gave much higher priority to the top two or three items on the list. Decision makers should focus on the top few items on the list when evaluating a region's funding priorities.

In most regions, the top funding priorities were either improving or widening existing roads, aiding transportation-disadvantaged persons, timing stoplights, or pothole repair. However, in many cases when pressed to choose the spending alternatives that should receive priority, pothole repair sank below the other top concerns in the region.

The major reason other spending alternatives dropped in importance was citizens often chose the most important priorities for their region. Ideally, they would like to see spending increase for many items but know they cannot afford the new taxes necessary to increase funding for more than a few options.

One exception to this general observation was the response from smaller areas like Trinidad and Alamosa. Conditions of most items were viewed so poorly that residents wanted increased spending in almost every area. The respondents from these areas did not indicate where they thought additional revenue would be obtained to fund these projects.

With the exception of pothole repair, the other major funding items remained priorities upon further investigation, especially increased funding for the elderly and disabled. The reason for the strong support was that people tended to view aid for transportation-disadvantaged persons as an important service that should be made available by society. However, it should be noted citizens generally did not understand the real costs associated with making significant upgrades in the transportation system for these individuals.

Other items viewed as being top funding priorities were improving and widening existing highways and better traffic light timing. Improving existing highways was identified as a priority to alleviate congestion and to improve safety conditions. Better timing of traffic lights was given priority because it was viewed as a low-cost solution that could be implemented quickly to alleviate congestion problems.

In addition to strong support for spending for transportation-disadvantaged persons in Denver and Colorado Springs, increased funding was an additional priority for mass transit projects. As previously discussed, in these areas, mass transit was viewed as one of the best ways to reduce congestion and mitigate existing or projected pollution problems.

The Durango participants believed quality road improvements, such as effective pothole repairs or road widening, could prevent rapid erosion of the roads. They believed quality work could save significant amounts of money that could be spent on other projects.

Willingness to Increase Taxes and Funding Allocation

Tax Increases

While the telephone survey indicated a willingness among citizens to increase their taxes to fund important programs, focus groups typically reacted negatively to the idea of a general increase in taxes.

Upon further probing, it became apparent most of the opposition to taxes was related to uncertainty about how taxes would be collected and spent. When presented with the idea of a specific tax of fixed duration, the public was much more supportive of tax increases to fund important transportation projects. However, some regions would not support new taxes for any reason. Akron, Montrose, Durango, and Trinidad were examples of regions that opposed taxes.

The focus groups showed a substantial lack of understanding of the state funding allocation process. An example was the Colorado Springs focus group. Participants were unaware of the source of funds for transportation or how funds were allocated throughout the state. There was a strong unwillingness to pay additional taxes until residents were sure the money would be allocated to their region. This opinion was prevalent throughout the state. Perceptions of the gas tax illustrated this problem. None of the participants knew how this tax was allocated or how it returned to the area from which it was collected. The general consensus was that allocation was based on population.

Overall, the public would be much more supportive of a tax increase if they were assured of a temporary tax and proper implementation of the money. Generally, the view was that higher gasoline taxes were an appropriate and fair means of obtaining increased transportation funds.

Funding Allocation

Generally, funding allocation decisions were viewed as unfair. These decisions were believed to be subject to political influence and used to fund major projects in the Denver area. While there was general acknowledgment that some redistribution of tax collections was necessary to build and maintain a statewide system, there was a persistent belief that the redistribution process was not conducted in a fair manner.

As previously stated, these perceptions stemmed from a lack of understanding of the derivation of monies for transportation and of the state allocation process. Many believed transportation dollars came primarily from taxes on gasoline; however, this belief carried considerable uncertainty. Moreover, there was little understanding of the allocation process throughout the state, creating perceptions of unfairness in revenue collection. Without accurate allocation information, citizens believed the process was politicized and unfair.

On the Western Slope, citizens believed tax dollars were diverted from the west to fund projects on the Eastern Slope. In smaller areas, people were convinced funds were diverted to the major cities in the state, particularly the Denver metropolitan area.

In areas that rely heavily on tourism, like Durango, there was a fear highway funds were allocated on the basis of population density, which did not reflect the true level of highway usage from tourism in these regions.

The Western Slope expressed strong concerns that building access roads to the new Denver International Airport would take funds away from highway improvements in their areas.

Decision-Making Input

Focus group members generally indicated they would like to have more input in the transportation decision making. Citizens indicated difficulty in making their views known. In many areas, concerns were expressed that officials made final decisions prior to a public meeting, so public input becomes ineffective. Participants indicated that if their participation made a difference in the overall planning, public input would increase.

Participants discussed concerns regarding public input at traditional meetings. They believed these meetings attracted special-interest groups and individuals with a vested interest in the outcome of the process. For this reason, there was widespread support for alternative means of gaining input from the public.

Methods suggested for increased input were voting on all transportation issues, newspaper ads advising of upcoming transportation meetings, direct mail, telephone surveys, and focus groups, such as the ones they were attending. Several participants indicated focus groups were informative, while allowing their opinions to be voiced. A participant from Fort Collins mentioned the process, Choices 95, as a good way to involve the public. These methods were all viewed as ways to get more input from the public, without the problems inherent in the traditional public meeting process.

Rural and isolated areas believed state decision makers paid too much attention to the major urban areas and overlooked the problems in their area. The Western Slope shared this perception because the public felt disenfranchised from the political and decision-making process.

Focus groups believed DOT officials should solicit input from the rural areas of the state. People in the Montrose area even suggested they would support a tax increase to station a DOT representative in the area.

Carpooling

Consistent with the findings on the telephone survey, many areas supported the idea of carpooling as a way to alleviate congestion and pollution problems in crowded urban centers. However, the support for carpooling lessened when it came to specific solutions to increase its use.

In rural areas of the state, the perceived benefits of carpooling did not outweigh the additional costs, such as reduced freedom and personal flexibility. In the urban centers, carpooling was seen as a viable way to reduce congestion problems and to help reduce vehicle emissions.

Most of the suggestions for carpooling incentives centered on tax breaks for businesses who encouraged their employees to use carpools or who provided carpool vans. There was much less support for building carpool lanes because of the high construction costs associated with these lanes. The uncertain benefits of increased carpooling did not appear to justify these high costs.

Overall, the primary incentive of carpooling was seen as the time and money saved compared with mass transit commuting. However, participants did not believe other incentives would increase carpooling.

CONCLUSIONS

Significant Focus Group Findings

The focus group meeting process resulted in many insights into the public's view of the transportation system and transportation planning. Decision makers should focus on the following areas.

Effective use of state resources is one of the primary considerations in system satisfaction. The public is most satisfied when the state identifies a problem, allocates resources, and implements a solution quickly and effectively. A prime element of satisfaction is for the state to avoid addressing the same issue year after year. Citizens believe that doing the job right the first time will free up considerable amounts of transportation revenue and significantly reduce waste.

Second, there is a general lack of understanding about the cost of providing public transportation. In almost every case, the public significantly underestimates the cost of building and operating mass transit systems. This misperception about costs is particularly true regarding the costs of building rail-based mass transit systems.

A third important finding is that citizens consistently favor improved public transit for transportation-disadvantaged persons, such as the elderly and the disabled. The public feels this service should be provided by society. Unfortunately, the public also considerably underestimates the true costs of improving transportation services for the elderly and disabled. Citizens believe that significant improvements can be made with nominal funding increases.

Fourth, while there is considerable support for an intercity rail system along Colorado's Front Range, there is very little understanding about the most appropriate use of different rail technologies. Citizens typically refer to all rail projects as "light rail." Additionally, a strong misperception also exists about the cost of building and operating rail-based systems. There is a perception that because of their efficiency, these systems are not expensive and may even be less expensive than buses.

Another important finding concerns decision-making input: citizens want to be involved in the decision-making process, but believe the input must be meaningful. Many indicate a reluctance to get involved in the process because they believe their input would not be taken seriously by officials. The perception of affecting the outcome of decisions is just as important to the public as having an opportunity to give input.

Sixth, citizens believe concerned officials are not planning for the future needs of Colorado's transportation system. There is a strong concern that without adequate planning, it will cost more than it should to solve future transportation problems. It is essential that planning be visible to the public, so misperceptions do not persist regarding inadequate planning for the future.

Postsurvey Focus Groups as a Research Tool

The experience of the research team indicates that postsurvey focus groups can be an effective tool in helping to evaluate the results of a survey. The major benefits of the postsurvey focus group are that it provides a valuable means to validate survey responses and allows researchers to further explore the reasons for those responses. Moreover, the postsurvey focus group provides the information agencies need to effectively target plans that address public concerns.

When important issues are identified in the focus group, researchers not only learn what the public wants but also have a unique opportunity to explore the best ways for agencies to address public concern on those issues. For example, focus group discussions revealed the public wants increased input into the state's transportation decision-making process, but citizens are concerned they will not have an opportunity for *meaningful* input. The focus group process allows for in-depth discussion of the best ways to provide input opportunities that the public believes would have a significant impact on the decision-making process. In this case, such information could prove invaluable in formulating plans that respond effectively, from the *public's* point of view, to calls for increased public involvement.

It is in this response planning process that postsurvey focus groups can be most beneficial. Once the significant issues are defined by the survey, the focus group can be used as a method to define the goals of a response that will focus on citizens' principal concerns. Officials will be able to target specific areas and provide information and education in the areas that will be the most beneficial to the public's decision making.

Another important finding is the public has a positive view of the focus group process itself. Focus groups increase feelings of involvement in the transportation planning process and provide an educational opportunity for the participants.

If the goal is to increase the effectiveness of public involvement in transportation decisions, then the postsurvey focus group can be an effective means of providing enhanced public access and improving the effectiveness of responses to public concerns.

FOCUS GROUP QUESTIONS

1. HIGHWAYS VERSUS TRANSIT SPENDING
   An important issue came up in the survey and had to do with the question of spending transportation tax dollars for new highways or mass transit like light rail or buses. ____ [number] of the local residents agree that it would be better to spend the money on mass transit rather than on new highways. How do you feel about this?
2. TRANSPORTATION FUTURE
   Think for a moment about the transportation system 5 to 10 years in the future? What do you think it will be like and why?
3. SYSTEM QUALITY
   Various aspects of the ____ transportation system were ranked in terms of their quality. I'm handing out a list of them now. Those items above the line received an above-average quality rating; those below received a below-average quality rating. Why do you think these items ranked so high or low?
4. OVERALL SYSTEM SATISFACTION
   ____ [number] of the ____ area respondents were not satisfied with the quality of transportation services within the state. Overall, are you satisfied or dissatisfied with the quality of transportation service and why?
5. AIR QUALITY
   ____ [number] of the ____ respondents said they would be willing to pay more taxes to improve air quality and almost three-quarters agreed that high-polluting cars and commercial trucks should be restricted from travel on high-pollution days. Do you prefer one or the other option or both, and why?
6. RESOURCE ALLOCATION
   The survey also asked which services should receive increased or reduced spending. I have another handout listing these services. The line separates those that should receive more spending from those that should receive less. Which, if any, do you feel deserve more or less spending and why? In other words, what is really important on this list?
7. WILLINGNESS TO INCREASE TAXES
   There was some willingness to pay more in taxes to fund important transportation services. ____ [number] of the local respondents were unwilling to pay anything more. How do you personally feel about paying more taxes for transportation?
8. ALLOCATING REVENUES WITHIN THE STATE
   ____ [number] of the ____ respondents believed that it was unfair to make one geographic area of the state pay for transportation improvements in other parts of the state. How do you feel about this? Do you agree or disagree, and why?
9. INPUT INTO DECISION MAKING
   ____ [number] of the local respondents believed they would like more input into transportation decision making. Would you like more input and if so what kind of input would be most meaningful to you?
10. CARPOOLING
    Increased incentives for carpooling were supported by ____ [number] of the respondents. Do you support increased incentives for carpooling and what types of incentives would work for you?

The opinions expressed in this paper are not necessarily those of the Colorado Department of Transportation. They are strictly the views of the authors.

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Organizational Coordination, Transportation Planning, and Hazard Mitigation: A View from the North Carolina Coast

PATRICIA J. MCGUIRE

Organizational coordination has long been recognized as an essential element of effective planning. Coordination is particularly important in sensitive coastal areas, where maintaining a balance between development and conservation is critical. Considered both irreplaceable environmental and valuable economic resources, coastal areas are subject to state and federal regulations concerning proper management and the minimization of risks associated with the high potential for natural hazards. Mandates have resulted in inter- and intragovernmental consistency requirements, however, which are often subsumed by the divergent goals and policies of the agencies involved. This problem was examined in the context of three transportation projects in coastal North Carolina, a bridge replacement at Sunset Beach, planning for a new bridge to Currituck Banks, and ongoing maintenance, relocation and long-range planning for the Outer Banks' primary road, NC 12. Case studies based on an evaluation of land use and transportation plans and interviews with highway engineers, emergency managers, and planners were developed for each of the projects. An assessment of the link between transportation improvements and coastal development, as well as an overview of the state and federal policy context for these activities, was prepared. Three policy issues were identified as inhibiting effective planning in coastal areas: the lack of an overarching mandate concerning the appropriateness and necessity of development in these areas, inattention to the powerful role played by infrastructure improvements in undermining hazard mitigation objectives, and the absence of requirements for cooperation among the government agencies that play primary roles in coastal management and development.

> But all these separate instances of planning suffer from two things: a lack of understanding of the social meaning of the plan, and a failure to achieve coordination with other organizations by dovetailing, under a common authority, into a broader scheme for regional and interregional planning. (*1*)

Lewis Mumford's perceptiveness and foresight into the dilemma of planning are as cogent today as they were 57 years ago. These two issues raised by Mumford, the understanding of social meaning and organizational coordination, remain today only peripheral elements of modern planning. Despite several decades of directives for public participation and the expanded consideration of social and environmental impacts, planning still suffers from a lack of attention to, and effective integration of, the social impacts of planning activities. The focus of this paper is Mumford's second point, the coordination of planning organizations. This problem is examined in the context of transportation planning in coastal areas of North Carolina, which have high potential for natural hazards.

Town of Carrboro, 400 Davie Road, No.18, Carrboro, N.C. 27510.

Coastal areas are irreplaceable environmental and valuable economic resources, and the need for coordination among business interests and environmental concerns is clear (*2–5*). The lack of coordination among public development activities has serious implications for the effectiveness of hazard mitigation efforts and leads to several questions. Should roadway needs in coastal areas be planned in the same manner as in any other area of the state? Are mandates for the movement of people and goods of greater importance than those developed to provide for public safety and environmental protection? Three factors make these questions particularly important:

1. Development in coastal areas of North Carolina is increasing. Population projections for counties in this area indicate an average increase in population of 13 percent between 1990 and 2010, with some counties experiencing growth rates higher than 35 percent. The rate of growth for the state is expected to be 10 percent for the same period.
2. Some natural hazards are predictable; all are inevitable. As population expands in areas of high risk, "disasters"—the confluence of human activities and natural hazards—are increasing in both frequency and severity. Since 1990, $31 million has been spent for emergency sand removal, beach nourishment, and sandbagging in numerous attempts to keep open the only highway between Nags Head and Hatteras on North Carolina's Outer Banks. Since 1974, $18 million has been spent on regular maintenance for the road.
3. Mandates for consistency of inter- and intragovernmental activities, rather than for comprehensive planning undermine hazard mitigation objectives. Resulting fragmentation prohibits serious consideration of questions concerning the appropriateness of development in hazard-prone areas and of the government's responsibility for its role in increasing people and property at risk.

Two state agencies play primary roles in coastal development and the implementation of hazard mitigation objectives, the North Carolina Department of Transportation (NCDOT) and the Department of Environment, Health, and Natural Resources' Division of Coastal Management (DCM). A third agency, the Department of Crime Control and Public Safety's Division of Emergency Management (DEM), although directly charged to reduce losses due to disaster events, plays a minor role in the process.

While NCDOT does not have a formal policy for transportation planning in hazard-prone areas, this study concludes that a number of economic, political, and governmental-structure factors, requirements of the Highway Trust Fund, the Official Map Acts, and plans for the state's intrastate system (*6–8*) serve to establish a de facto policy to increase road construction in coastal areas. If the proposed schedule for the intrastate system is met, four-lane highways will be in reach of 96 percent of the state's population within a decade (*9*). These policies support increased development in coastal areas with high potential for natural hazards despite the hazard mitigation and coastal management mandates that are in place.

Unlike NCDOT, DCM has a clear mandate to facilitate the balanced development of coastal areas. As the staff to the Coastal Resources Commission, DCM implements North Carolina's Coastal Areas Management Act by conducting environmental research, setting guidelines, and overseeing the preparation of local land use plans. The agency is also responsible for reviewing permit applications for consistency with local land use plans. Despite its clear mandate to "provide a management system capable of preserving and managing the natural and ecological conditions of the estuarine system . . . and perpetuate their natural productivity and their biological, economic, and esthetic values" (*10*), DCM serves primarily in a "supporting capacity" to local governments and consequently has no power to enforce its guidelines (*11*). In the realm of transportation, the Coastal Areas Management Act (CAMA) directs DCM to "establish policies, guidelines and standards for . . . transportation and circulation patterns . . . including major thoroughfares [and] transportation routes" (*12*). In actuality, many jurisdictions rely on thoroughfare plans prepared by NCDOT for the transportation components of their local land use plans. As a result, DCM's responsibility for developing a coastal management program that balances development and conservation must often yield to the interests of other agencies.

These thumbnail sketches illustrate a lack of philosophical alignment within and between the state agencies that play the largest public roles in coastal development. A discussion of hazard mitigation and the role transportation improvements play in coastal development further details these interagency contradictions. These issues are examined through case studies of three transportation projects in coastal North Carolina, a bridge replacement at Sunset Beach, the proposed construction of a new bridge across Currituck Sound to Corolla, and ongoing maintenance of the Outer Banks portion of NC 12 (Figure 1). The complexities and difficulties of these projects clearly illustrate the lack of concurrency with imperatives to reduce risk of loss from natural hazards and the inadequate coordination between emergency managers, coastal managers, and transportation policy makers. A long-range, interagency planning process recently initiated for the Outer Banks' primary north-south road, NC 12, is presented as a possible solution to the lack of coordination.

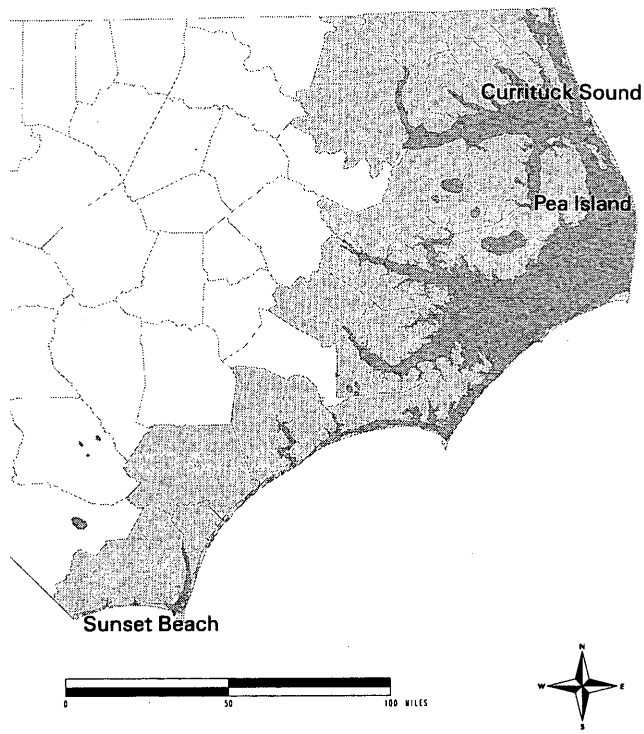

FIGURE 1 Location of three case study transportation projects in eastern North Carolina.

TRANSPORTATION AND HAZARD MITIGATION: POLICIES IN CONTEXT

Hazard Mitigation and Coastal Areas

In many ways, urban growth in coastal areas of the United States is under the spell of a fatal attraction in which the "areas most attractive to new development are often those most dangerous to life and property" (*2*). Policy makers are caught in the middle, bound by the responsibility of protecting people and property from natural hazards without too severely limiting the private development market. "Great storms . . . are, in the grand scale of time, normal events, recurring again and again, more or less regularly" (*13*), yet they are perceived as catastrophes by human observers whose collective memory is, by comparison, short. Short memories of hazardous events and large investments in high-risk areas have resulted in the repeated reconstruction of destroyed public utilities—an outcome that has been widely recognized as costly and inefficient (*4,14*). In 1976 the United States federal government modified the disaster determination process administered by the Federal Emergency Management Agency (FEMA) to include the preparation of mitigation plans for future events (*15*). The concept of hazard mitigation is not new. Humans have always adapted construction techniques to high winds, battened down in the face of hurricanes, or evacuated in the path of volcanic eruptions. In spite of recent initiatives, the cycle of "build, destroy, rebuild" (*2*) is supported at tremendous cost, much of it directly subsidized (and largely hidden) through disaster assistance and flood insurance, or indirectly through tax breaks for second-home buyers and funds for a variety of public facilities improvements.

A common criticism of the mitigation planning process is that there are few requirements for the coordination of efforts. Emergency managers are typically responsible for preparing plans for responding to disasters. Their work primarily addresses the preparedness (events preceding the emergency) and response (short-term emergency aid and assistance) stages of the disaster response process (*2*). The scope of transportation in hazard mitigation planning is usually limited to discussions of evacuation routes and techniques. In the aftermath of hazardous events, planning activities are fragmented rather than linked. Reconstruction and relocation decisions are assigned to highway engineers. Land use policies concerning the type and amount of development are left to local planners. While consistency requirements are in place, the unequivalent levels of government, planning resources, and organizational goals from which these plans are developed undermine the joint efforts that are necessary under the unique characteristics of high-risk areas. Coordination of the goals, objectives, and policies of the relevant governmental agencies must increase if two elements of hazard mitigation, decreased vulnerability and reduced exposure, are to ever be effectively realized.

Role of Roads and Bridges in the Coastal Development Process

Infrastructure and transportation systems play a vital role in the development of coastal areas—barrier islands are largely inaccessible without bridges, causeways, or ferry services, yet these improvements, and the development they support, inhibit the natural maintenance processes of these islands. Like most barrier islands, the narrow chain of sand that buffers the North Carolina mainland from Atlantic winds and tides is in a state of "dynamic equilibrium" (*13*). The islands, from sea to sound and beach to marsh, are in motion, rolling over on themselves with the wind and waves reshaping shorelines in response to long winter storms or brief, powerful hurricanes (*13,16*). Infrastructure investments introduce an element of permanence alien to these environments. Concomitant growth in seasonal and year-round residents increases the sense of permanence, and additional improvements become necessary to protect the health and safety of coastal immigrants. The combined effects of purpose (infrastructure to improve access to the coast) and need (investments to provide adequate evacuation capacity) bring into sharp relief the critical nature of transportation in coastal areas.

Transportation networks play two roles in the coastal development process. First, roads and bridges increase accessibility to barrier islands by expanding the transportation system from intermittent boat or automobile-carrying ferry services to roadways open around the clock. Second, these road networks are vital to the evacuation of the increasingly large number of people who are drawn to vacation opportunities at the shore. While there is an extensive literature on the relationship between land use and transportation (*17–20*), the strength and direction of the relationship is far from clear. Land use and transportation planners have found it difficult to develop models that account for the many variables that come into play in decisions regarding individual relocation or improvements to the transportation system. In the case of the islands that make up North Carolina's coastal areas, the cause-effect relationship is clearer, and most believe that "highways bring development" (*16*). Schoenbaum (*16*) presents a sketch of the manner in which access improvements lead to a never-ending cycle of transportation-related construction:

> . . . before the construction of bridges and roads, there was very little development on North Carolina's barrier islands. Nags Head was a small resort town on Albemarle Sound until the bridges and roads were constructed in the 1930s. Other islands "benefited" from the military roads and bridges constructed during World War II. Highway access has increased the value of property on the island tremendously. . . . This is why the pressure for roads and bridges comes not so much from the people who *live* in the area but from those who want to *develop* it.

Schoenbaum's views on the role of transportation improvements in promoting development is echoed in much of the literature on transportation in coastal areas. In *Transportation Access over Currituck Sound,* Howard Needles Tammen and Bergendoff describe the construction of a bridge connecting the Outer Banks to Nags Head in 1928 as the "prime mover for the beginning of development of the northern outer banks" and conclude that "adequate vehicular access proved to be the catalyst for accelerated development of the Dare county segment of the outer banks from Nags Head to Duck" (*21*). The point was driven home in a 1990 trial concerning the inadequacy of an environmental assessment completed for a bridge replacement in Sunset Beach, North Carolina. U.S. District Judge, W. Earl Britt ruled that the NCDOT's and the Federal Highway Administration's argument that it is zoning changes that will cause increased development, and not the bridge, completely ignores the regulatory definition of "indirect effects" that they are required to abide by: indirect effects are those caused later in time and may include growth inducing effects (*22*).

The consequence of increased development of coastal areas is that, at some point, road and bridge improvements are necessary to move large numbers of people out of harm's way. Evacuation is only one component of a hazard-mitigation program, but this critical element is completely dependent on the capacity of the transportation network. As Godschalk and others have noted, "for most built-urban areas in threatened locations, there is no other apparent alternative to protecting the population from storm forces" (*2*). Local land use plans have begun to utilize a "carrying-capacity" approach to analyzing their transportation systems for determining appropriate levels of development (*11*). Transportation was listed as the first Emergency Support Function (ESF) of FEMA's recently developed Federal Response Plan (FRP) for disasters (*23*). The need for a clearly defined and coordinated transportation policy with regard to coastal development and the hazard mitigation process is evident.

CASE STUDIES OF TRANSPORTATION PROJECTS IN COASTAL NORTH CAROLINA

Planning for three transportation projects in coastal North Carolina is currently under way: the replacement of a bridge over the Intracoastal Waterway to Sunset Beach, the proposed construction of a new bridge across Currituck Sound to Corolla, and long-range planning for a troublesome stretch of NC 12. The complexities of these projects clearly illustrate the lack of concurrency with imperatives to reduce risk of loss from natural hazards and the inadequate coordination between emergency managers, coastal managers, and transportation policy makers.

Sunset Beach Bridge Replacement

Sunset Beach is located in Brunswick County at the southernmost tip of North Carolina's Outer Banks. The town's recently completed land use plan calls for Sunset Beach to remain a "family beach." Residential development of the island dates to the early 1950s when a single-lane, barge-supported swing bridge was constructed over the inland waterway to connect the island with the mainland. Soon after, the name of the island was changed from Bald Beach to Sunset Beach. Residential development, primarily for seasonal, recreational uses, continued. Recreational development of the mainland has occurred as well, and the area now boasts a score of golf course communities and the highest property valuations in Brunswick County. Both the mainland and the island have seen increasing rates of growth in the past 10 years and are estimated to be 60 percent built-out. The remaining capacity is expected to be reached in about 10 years, and the town is currently requesting funds to develop water and sewer treatment facilities to meet current and future needs without any further environmental impacts.

The bridge was privately maintained and operated until 1960 when the state agreed to take over these functions. Following a number of initial structural alterations and repairs, the state has maintained and operated the bridge since the early 1960s. By the early 1980s, time and use had taken their toll, and NCDOT initiated a planning process to determine what should be done with the bridge. In light of the increase in development on Sunset Beach and the design capacity and condition of the bridge, NCDOT developed a number of alternatives for replacing the structure. The initial environmental assessment process, which included assessment of consistency with the CAMA, was conducted. The favored alternative, replacement of the single-lane, pontoon bridge with a double-lane, high-rise, fixed-span bridge was identified. As required under NEPA, an Environmental Assessment was prepared, circulated, and approved prior to the "Finding of No Significant Impact" (FONSI).

There had been some concern expressed by residents of Sunset Beach over the selection of the high-rise option at NCDOT's public informational meetings and at the public hearing when the preferred alternative was presented. Approximately 25 people attended each of the two public meetings and 80 people attended the public hearing (*24*). Written comments were received from 147 citizens, 75 of whom were opposed to the project (*25,26*). Several reviewing agencies were also concerned with the potential impacts associated with the bridge replacement. NCDOT did not consider these comments to represent a serious objection. The town council was very much in favor of the project and adopted a resolution on October 11, 1982, calling for NCDOT to either renovate the structure or facilitate other measures that would improve its safety. The citizen and review agency comments did raise some concern, however, and the bridge-replacement project was placed "on hold" shortly thereafter (*22*). While some objections were raised during the public hearings, no opposition was recorded during DCM's review of NCDOT's permit request. A Coastal Resources Commission permit was issued in early 1985.

In 1985, the project was revived and 200 people turned out for the public hearing at which five alternatives were presented, with the high-rise option still the preferred bridge replacement option. Written (54 pro and 82 con) and verbal (11 pro and 30 con) comments were offered (*24*). In spite of the opposition, NCDOT decided to proceed with its preferred alternative and the Sunset Beach Town Council adopted a resolution of unanimous support for replacement or improvement of the existing bridge. NCDOT's second FONSI addressed some of the concerns of citizens and reviewing agencies, but in early 1986 the project was still on hold as a "direct result of the strong opposition [residents] and others have expressed" and the fact that much-needed repairs had extended the projected service life of the bridge to 1994 (*22*). During the next 2 years, the CAMA and CZMA consistency requirements were met, a bridge was designed, and the right-of-way was acquired. The bid notice was released and a contractor selected. As the contractor began to mobilize and prepare the site, opposition coalesced. Members of the Sunset Beach Taxpayers Association filed suit against NCDOT for failing to complete an Environmental Impact Study (EIS) for the project. Critics claimed that the new bridge would drastically increase development pressures in the Sunset Beach community, threaten wildlife species, and destroy the link between the mainland and island portions of the community. The suit was successful and a court order was issued making all of NCDOT's actions null and void and directing the agency to comply with the environmental impact assessment requirements of NEPA as it had failed to do.

As part of the EIS, NCDOT has hired consultants to determine the impacts of the existing bridge on the water and road traffic and to assess the direct and induced land use impacts and the economic, visual, and water-quality impacts of three "reasonable and feasible" bridge alternatives. The three alternative designs include a 15-ft drawbridge (low-rise), a 30-ft drawbridge (mid-rise), and the 65-ft, fixed-span (high-rise) bridge (*24*). Land use and economic impacts have been evaluated through a case study of "the historical impacts of bridge replacements on two neighboring islands, Holden Beach and Ocean Isle Beach" (*24*). This case study indicates that the impacts of high-rise bridges have been minor. While several large projects have been constructed, the rate of development in both communities has slowed since the bridge openings, perhaps in response to changes in federal tax laws or the downswing in the national economy (*24*). In spite of this, both communities have seen an increase in day visitors. The report states that "more dependable bridge access did enable business owners to consider locations which previously had been too inconvenient" (*24*). Sunset Beach has actually had a higher rate of residential development than the neighboring towns, leading NCDOT's consultants to conclude that the "character and pace of development is more attributed to the Town's attitude toward growth and the impact of the national economy, rather than the existence of high-level bridge structures" (*24*). The study does not yet consider the possibility that the continued growth in Sunset Beach may be the result of a unique, small-town character associated with the limited access to the island afforded by the swing bridge.

Traffic impacts associated with the various replacement alternatives are being assessed. A vessel-height survey was conducted to determine the height and frequency of watercraft passing through the existing drawbridge, and vehicular traffic counts were under way in 1994 (*25*). Travel patterns for vehicles and vessels in coastal areas are markedly different, particularly for larger vessels. Peak vehicular traffic occurs in the summer, but vessel traffic peaks occur in the spring and fall because many yachts and sailboats follow seasonal weather patterns. The study revealed that during the peak tourist season daylight hours the low-, mid-, and high-rise structures would allow unrestricted passage of 37 percent, 67 percent, and 100 percent, respectively, of the vessels.

Social impacts are also being considered. Peggy Hayes, one of the consultants working with NCDOT on the EIS, believes that development trends and land use policies are the strongest forces affecting development on the Outer Banks. As part of the land use plan update process in 1992, Hayes prepared a questionnaire addressing a number of issues that had been identified during a public meeting. The survey was mailed to a sample of property owners from the town and extra-territorial area. Of the 200 questionnaires sent out, 124 were completed and returned. However, the voluntary nature of the response may bias its representativeness. Two questions addressed the bridge replacement issue. The first question was "What is your preference for a bridge to the island?" Fifty-seven respondents (48 percent of the total) indicated support for maintaining the one-lane bridge. Overall, 73 percent of the residents who responded to the survey were in favor of maintaining the current bridge or replacing it with a mid-rise structure. To a more general question concerning "the most important issue facing Sunset Beach," two residents indicated "no high-rise bridge" (*26*). Fourteen others responded that a new bridge was needed, and only one resident felt that the most important issue facing Sunset Beach was that the existing bridge did not allow safe evacuation from the island.

In 1992 Sunset Beach prepared its land use plan update. The plan was officially adopted by the town council on March 13, 1993, and was certified by the Coastal Resources Commission 13 days later. Unlike those of several neighboring communities, the plan contained specific statements concerning transportation. The first statement called for improved bridge access through renovation or other measures. The second expressed concern over the safety and evacuation capacity of the swing bridge and called for "more reliable" access (*26*).

By the time the update was prepared, the issue of the bridge was growing in intensity. Although there appears to be a feeling among certain residents that the elected officials do not represent the collective interest of the community, the policy statements in the land use plan are not specific as to the type of bridge that should serve the community. As a further assurance of good faith, "the town has enacted a 35-foot building height requirement . . . which can only be changed by public referendum" (*24*).

Mid-Currituck Bridge

From the late 1970s to the early 1980s, Currituck Banks was the least-developed of North Carolina's string of barrier islands. Speculative purchases and subdivision had been raging for nearly three decades, but northeastern North Carolina was a rural, agricultural area and the Outer Banks had never seen more than limited development for lighthouse operations or hunting lodges (*13*). Growth in the Norfolk, Virginia, area began to exert pressure on Currituck in the early 1970s and NCDOT road building and expansion were increased. For many years, environmental and development interests engaged in heated debates over the appropriateness and necessity of developing the entire Outer Banks. A key issue in this debate was the construction of a road connecting the outer banks of Virginia to Currituck Banks. Although long discussed and oft-planned, the road has never been constructed (*13*). Following several years of debate, NC 12 was extended to Corolla, a community that could only be reached by a sand road for some time. Development has boomed in the interim, and over 270 residential structures have been constructed in the beach communities north of Corolla. Currituck County's *1990 Land Use Plan* (*12*) identifies the lack of access to these residences as the most controversial and complex transportation issue facing the community. Residents of a number of unincorporated areas drive north along the beach to reach their homes. Development is increasing despite this inconvenience, which suggests that the state's firm policy that "no road would be built north of Corolla" (*13*) may one day be breached.

In spite of legal barriers and the existence of public and private wildlife refuges north of Corolla, the no-road policy is particularly vulnerable at the present time. Because of increasing development on Currituck, traffic along NC 12 is rapidly increasing. Poplar Branch Township, which encompasses the lower portion of the Currituck Outer Bank and part of the mainland, is the fastest growing of Currituck County's four townships (*12*). The distance to the closest soundcrossing bridge, Wright Memorial from Southern Shores to Point Harbor, is 20 mi. Currituck County officials claim that a mid-sound bridge is needed to increase access to service-needy residents on Currituck Banks. First proposed in 1978 (*27*), a feasibility study was completed in 1989, and, using the provisions of the Official Corridor Map Act, a corridor was preserved for a landing site of the bridge near Corolla. Revenue bond, federal, and state financing alternatives were examined in the study. Subsequent attempts to obtain federal funds were unsuccessful, but the project, with construction scheduled for 2003, was included in the 1991–1997 Transportation Improvement Program (TIP) (*28*). The provision of emergency medical services and hurricane evacuation are the two primary arguments presented in the 1991 Currituck County land use plan in support of a bridge, but the state's 1993 TIP identifies a different purpose—that the bridge will "enhance the accessibility of the Outer Banks and benefit the important tourism interests" (*28*).

In its latest iteration, the project is only in its early planning stages. Despite the potential impacts and need for coordination, permits staff at DCM learned from newspaper articles that the project was being revived. While this may seem irregular, it is not entirely so. Scoping meetings are held with a variety of agencies to identify potential areas of impact that should be addressed in the environmental impact assessment process. However, the EA or EIS process allows official review and comment only at the draft report stage. Many alternatives or impacts have already been dismissed by this point in the process and the boundaries of analysis have been set by NCDOT. In accordance with the schedule outlined in the 1993 TIP, a contractor was selected in March 1994 to begin an EA. While a landing location at Corolla has been reserved since 1991, three alternative takeoff points have been identified, all linked to existing corridors in an effort to minimize the environmental and economic costs associated with cutting through the large swamp that borders Currituck Sound on the mainland side.

Both bridge and nonbridge alternatives are being considered in the EA, and the impacts to be addressed range from land suitability to archaeology. Like many projects of this magnitude, the momentum associated with a conservative estimate of $48 million for planning and construction seems to favor a build alternative. The time costs of vacationers must be weighed against those of schoolchildren commuting to the mainland, and the revenue associated with increased development must be weighed against the costs of disaster relief. These questions are of importance when any expensive public investment is considered but are critical when a project of this scope is proposed. The link between land use changes and development is not always clear. A bridge has provided access to the northern Outer Banks since 1928, when a toll bridge was constructed to connect Manteo and Nags Head (*21*). Subsequent transportation improvements were followed by other development, but no public road served Currituck County's portion of the Outer Banks until 1984. The justification for incorporating the private road that ran from Duck to Corolla into the state system at that time was access—access to the beach by vacationers, access to community services on the mainland by taxpaying residents, and access to the island community by government employees. In the past decade, development has increased despite only limited improvements in access, and has led some to conclude that "some portion of the growing number of . . . residents seek, or at least accept, the seclusion afforded by this access restriction" (*21*). If suboptimal access does not prevent development, the county has identified a condition that may—limited potable water supply in the northern portion of the county. This condition has led to a call for comprehensive studies of potable water supplies in advance of constructing a new bridge (*12*).

The strong link between access improvements and development emphasized here and NCDOT's policy concerning NC 12 are contradicted on two points by the resumption of planning for a mid-Currituck bridge. First, neither the need nor the purpose for a bridge has been clearly established. The county land use plan belies itself, both supporting the bridge's inclusion in the TIP and recommending caution because of potential impacts of increased development on the water supply, and the TIP emphasizes the tourism and economic development benefits of this "critical" structure. Second, selection of a Corolla landing site is incomprehensible if this is to remain the northernmost town with full public road access. Development pressure would substantially increase in Corolla as would development in the northern beach communities. Some residents of these communities are already calling for the state to provide improved access to their holdings. An increase in the number of people at risk would necessitate road construction and open up more areas for development.

Long-Range Planning for NC 12

Maintenance and upgrading of the Outer Banks' main artery is a continuing sore point between NCDOT and most of the agencies charged with determining the negative impacts of publicly funded projects. By their very nature, barrier islands are in motion. Wind-driven sand, wave overwash, and downstream currents move these islands landward and southward. As is obvious, the mobile nature of barrier islands is somewhat at odds with the stable requirements of roadways (at least when asphalt, concrete, and lots of time and money are required in their construction and maintenance). NC 12 is regularly in need of repair.

Because of a lack of long-range planning and accounting methods that separate maintenance activities from emergency cleanup, most of these repairs have been carried out as stopgap measures. A prime example is the 6-mi stretch of roadway south of Oregon Inlet. In recent years, over 0.5 million yd^3 of sand have been pumped from the sound to lengthen the beach, and sandbags have been installed to further protect the road from overwash. Following Hurricane Emily in September 1993, a portion of NC 12 north of Buxton was washed out, and NCDOT requested permission from the Coastal Resources Commission (CRC) to lengthen the beach with sand from Pamlico Sound. In 1992, NCDOT had initiated a study of long-range alternatives for this section of roadway, but the consideration of impacts on the nearby National Park and National Wildlife Refuge were complicating the analysis and no specific solutions had been identified. The CRC was reluctant to grant permission, calling instead for NCDOT to develop a more permanent solution to the problem of overwash in this area. When the project was delayed, local landowners appealed to the governor's office. Soon after, a declaration of emergency was issued on the grounds that the road condition severely limited access to residences in Buxton and Hatteras, and the beach nourishment permit for the project was issued by the CRC. Clearly, something had to be done. Over 20,000 structures are located on Hatteras Island and, according to NCDOT Assistant Branch Manager Barney O'Quinn, unofficial state policy is to quickly correct deficiencies in the transportation system and prevent or minimize damage to the tourism industry.

Conflicts such as these with the state's policy toward coastal management have led to the initiation of a long-range planning process for the approximately 80 mi of roadway between Oregon Inlet and Ocracoke. Seven federal and state agencies are involved in the "Interagency Task Force on the Transportation System for the Outer Banks" (*29*). Using a "partnering process" combining staff and funds from the participating agencies, the task force is to develop a unified approach to the planning process. Three objectives identified for the process, to be reached over 5 years at a cost of $7.8 million, include protecting and maintaining the transportation system for the Cape Hatteras National Seashore and the Pea Island National Wildlife Refuge, providing background studies and a scientific basis for making sound decisions on transportation system improvements, and ensuring that the natural barrier island system on the Outer Banks is preserved and subjected to minimal environmental impact (*29*).

NCDOT initiated this process in response to criticism that it was not considering the cumulative impacts of road maintenance on this vulnerable stretch of the Outer Banks. Since most land and water projects on the Outer Banks could affect the entire area, the process is also an attempt to coordinate the efforts of many agencies and maximize the effectiveness of their sand management, channel dredging, and hurricane-evacuation efforts. Included in the scope of work is a comprehensive assessment of transportation alternatives, including bridges, causeways, ferries, and even a buyout of all private property. The agency has already committed $1.5 million to the process and is anxious for it to succeed. Scarcely past the embryonic stage of development, the partnering process may hold part of the key to successful integration and coordination of the many mandates that affect public involvement in coastal development.

IMPLICATIONS OF THIS ANALYSIS

The analysis of the collective policies and actions of NCDOT and DCM has clearly shown that the state of North Carolina does not have a coherent policy concerning the provision or upgrading of transportation infrastructure in coastal areas with high potential for loss from natural hazards. NCDOT does not have a specific policy for coastal areas. Rather, certain mandates (eg., the Highway Trust Fund or unofficial policy concerning the tourism industry) direct increased roadway development along the coast without regard for the potential hazards of such development. Clearly, political and economic factors play an important role in transportation policy throughout the state, and well they should. The Highway Trust Fund was devised to formalize some of these interests and to equalize highway spending around the state. Its effect in coastal areas has been to facilitate construction of roads and bridges that both encourage development and support evacuation. Unfortunately, the impacts of such transportation investments on fragile and unique barrier island ecosystems are not adequately addressed.

Local land use planning is considered an effective means of mitigating hazards through development management, such as density and height restrictions and public facilities requirements. Both the CZMA and the CAMA stress local land use planning but do not explicitly require that the type or capacity of transportation systems be considered or determined by the communities. Further, a significant element in this process, the transportation network, is managed at a different level of government. The impacts of a transportation improvement on local residents may be considered secondary to its benefit to the entire state. The converse is true as well. A transportation improvement that enhances access and developability of a certain area may also increase the responsibility of the entire state for facilitating the increased loss of life or property. What are the costs of allowing and supporting development of high-hazard areas? How much risk, and therefore responsibility, does the state accept? The ensuing contradiction is evident. "We are caught in a dilemma" laments Barney O'Quinn, Assistant Branch Manager for the Planning and Environmental Branch of the Division of Highways. "Where is DOT inducing development and where is it supplying to meet a need?"

What appears to be an oversight by policy makers in North Carolina in establishing an overarching policy and process for coordinating these activities results from the complexity of problems facing the state concerning the rapid development of coastal areas and the difficulty of balancing the benefits of coastal development and the costs of loss from natural hazards. By allowing policy to be developed in separate governmental areas, each acting as a distinct entity, the resulting competition of interests and lack of comprehensive planning disables the effective implementation of federal and state mandates to reduce the loss of property and life and to protect this fragile environment. These compromises ensure that larger questions are never addressed. The role of transportation policy in this process is not clear. In most cases, transportation improvements are seen as accompanying development trends. Transportation is a key element of the developability of coastal areas. As a result, where the political and social will is for development, transportation improvements are accepted as givens and rarely discussed. Only in the case of the CBRA has government, at any level, recognized the strength of this relationship and attempted to manage coastal areas through the prohibition of federally funded infrastructure improvements.

The long-range planning process recently undertaken by NCDOT is a step toward the organizational coordination and regional planning Mumford was calling for nearly 60 years ago. This process may even allow for the parties involved to look beyond their particular needs and consider the larger, difficult questions concerning the appropriateness and necessity of development in hazardous areas and the benefits of a cooperative, comprehensive process of planning and environmental management.

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Parking Restrictions in Employment Centers: Implications for Public Transport and Land Use

RUDI HAMERSLAG, JON D. FRICKER, AND PAUL VAN BEEK

Measures designed to discourage automobile use and encourage use of alternative modes need to be carefully evaluated to avoid unintended consequences. The impact of a particular set of protransit parking policies on mode and destination choice was examined. A travel demand model with an integrated spatial allocation land use module was used to expand the analysis beyond the narrow question of how mode choice changes within the zones that are subject to the transit-friendly parking policies. Parking supply and/or travel costs to zones with parking restrictions can be adjusted in the model to reflect the restrictions. Discouragement of car travel to some locations influences not only mode choice but can, over time, lead to changes in destination choice and land use patterns that can be detrimental to public transportation. The extent to which such land use changes will take place will depend, in large part, on the nature and implementation of existing land use policy. The desired reduction in automobile traffic is possible only if appropriate parking and business location policies are coordinated and enforced. A stringent parking policy without consideration of long-term impacts on land use development is likely to have little impact on networkwide automobile use but may cause a substantial decline in public transportation ridership.

Advocates of public transportation cite, among other factors, the abundant supply and underpricing of automobile parking as explanations for transit's inability to attract more riders. Free parking is provided by many central-city employers, in what amounts to a tax-exempt benefit to workers who commute by automobile. In the United States, the value of this benefit often exceeds the $60-per-month tax-exempt limit on employer subsidies to workers who use public transit. Many downtown merchants validate customers' parking receipts, making the use of the commonly preferred mode (automobile) even more desirable and transit correspondingly less attractive.

In Europe, despite traditions of high (relative to the United States) levels of transit use, automobile use is on the rise and parking restrictions are being instituted in the old city centers. These restrictions take the form of new or increased parking charges and/or a limitation on the supply of parking spaces. Do such parking strategies tend to equalize the relative perceived costs of auto and transit use, to the relative benefit of transit? Or, does the introduction of new restrictions on auto use initiate (or accelerate) a more general phenomenon: the reallocation of urban activity away from the city center or other urban concentrations of trip ends? If this reallocation is a likely result, the impact of parking restrictions on mode choice should be reexamined in this broader context.

A spatial allocation model developed at Delft University (*1–3*) offers a tool for evaluating the impacts of transportation policy on land use. The spatial allocation model is part of a dynamic multimodal transportation model that describes the interaction between the transport system and land use. The service levels of the public transport and road systems, as well as demographic and economic variables for a region, are used to estimate developments in the location of employment and residences. The spatial allocation model can be used to investigate the impacts on land use of various levels of automobile parking restrictions. More importantly, it can be used to evaluate parking management strategies to determine how well they improve the ability of public transport to serve basic urban mobility needs as part of an integrated transportation system in a region. This paper demonstrates how such an evaluation can be carried out and what results can emerge.

DUTCH LOCATION POLICY

In the Netherlands, a national "ABC" location policy has been established by the Ministries of Land Use and Transportation in an attempt to influence the use of automobiles. The policy attempts to control the location of new employment, subject to the quality of public transportation service. Businesses and facilities that tend to attract large concentrations of work trips are supposed to locate at places that are well served by public transportation or can be easily reached by bicycle. Such a policy seeks to cause positive impacts on economic efficiency and the environment. Businesses with less intensive personal transportation requirements, but with a need for efficient goods movement, are to be located with good access to the road network. Because the shift from unnecessary auto use to public transit and bicycle use is not likely to occur where there is an adequate number of automobile parking spaces, parking policy has become an important part of Dutch location policy (*4*).

The most important part of the parking policy is the reduction in long-term parking places for home-to-work trips in certain locations. The locations are defined in terms of their accessibility to public transportation:

- A locations are very well served by high-quality public transportation.
- B locations are in the vicinity of good public transportation and are accessible by automobile.
- C locations are easily reached by car but are not well served by public transportation.

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Stronger parking standards are being instituted for new developments in A and B locations. These vary, depending on whether the proposed development would be inside the Randstad (the coastal area of the Netherlands that includes Amsterdam, The Hague, and Rotterdam) or elsewhere. Beginning in 1995, national government targets for the number of parking spaces per 100 employees are

- A locations in the Randstad and other designated urban districts, 10;
- A locations elsewhere, 20;
- B locations in the Randstad and other designated urban districts, 20; and
- B locations elsewhere, 40.

These standards apply to locations or zones as a whole, and not to individual businesses. Formerly, the parking policy was applied only to public parking spaces. As a result, businesses often provided numerous parking spaces on their own property, effectively nullifying the parking policy in that area. For example, studies in the Dutch cities of Hengelo and Enschede (*5*) showed that about 75 percent of the commuters parked on company property. Zoning regulations to cover the supply of parking on private property are being formulated in support of the 1995 parking policy.

The establishment of businesses in A and B locations will depend on how these regulations are interpreted and enforced. The policy is implemented by prohibiting the establishment of specified businesses outside of A and B locations. Although the ABC policy is formulated by the national government, the actual policy is carried out by lower-level jurisdictions, such as cities or transportation authorities, which may use stricter or looser interpretations. This study will assume a uniform application of the ABC location policy within a region and confine itself to examining the changes that follow from certain specified parking policies. Toward this end, use is made of a research module in the transportation and land-use software TFTP, to which parking constraints have been introduced.

NETWORKS

A hypothetical but realistic urban area that exemplifies the land-use and public transportation policy issues described herein is shown in Figure 1. The public transportation network consists of heavy rail lines [thick lines in Figure 1 (*left*)] and bus lines [thin lines in Figure 1 (*right*)]. Links without public transport service are not indicated. Parking constraints are applied in zones that are served by rail lines. [These zones are marked with an enlarged shaded circle in Figure 1 (*right*)].

PARKING CONSTRAINTS IN TFTP

The Model With Elastic Constraints

The software package TFTP (*6*) was originally developed for educational purposes to demonstrate the functions of commercial network-based travel demand modeling software. It has evolved into a research tool as well, incorporating components such as the spatial allocation land use model (*3*) used in this study. Figure 2 gives an overview of the revised TFTP software structure. Inputs to TFTP are the road network, the public transportation network, and the current dispersion pattern of residences and workplaces. In the road and public transportation networks, origin-destination (O-D) travel times are calculated. The origin and destination totals are based on current land use patterns. With these trip end and travel time data, O-D matrices for each mode can be calculated. This information is used to determine traffic flows in the auto network and passenger flows in the public transportation network.

The model used in this study calculates distribution and mode choice simultaneously and uses feedback from land use. The model's elastic constraints (*7*) allow for endogenous modification of trip end totals, which reflect a change in land use patterns in response to accessibility. Feedback from car flows to car time to take into account the influence of delay from congestion (*3*) hasn't been applied this time. Also the feedback from public transit (PT) flows to the PT network, the public transit optimization model (*7*), hasn't been used in the analysis that follows. However, for this study, a parking supply constraint has been added to the TFTP model.

TFTP has already been applied to a variety of study areas. It has provided a good representation of existing and forecasted flows and land use patterns in locations such as Washington, D.C. (*3*) and the San Francisco Bay Area (*8*). It is, therefore, reasonable to use the

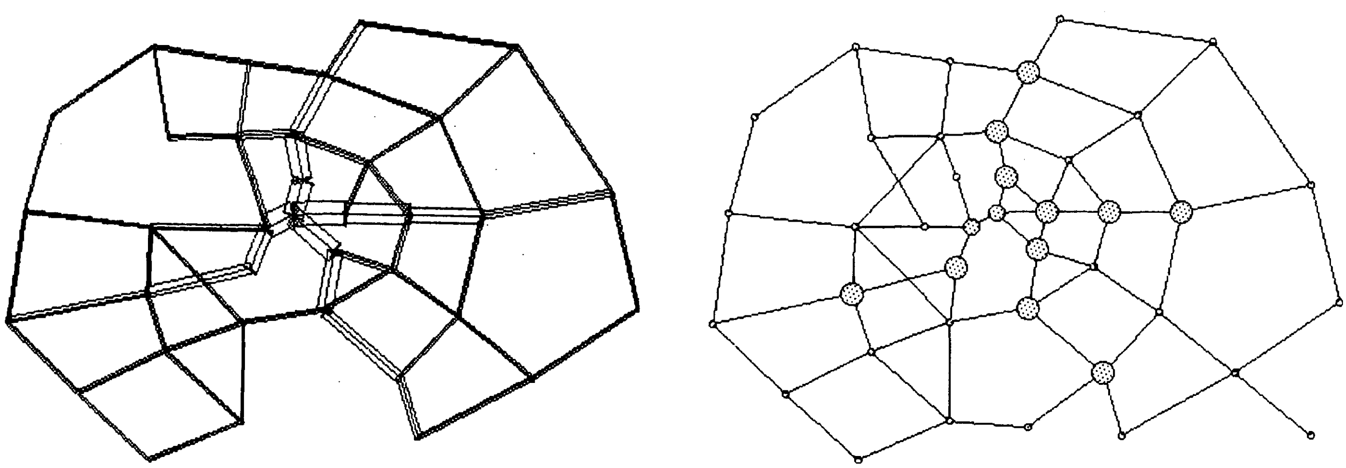

FIGURE 1 Traffic flows in the public transport network (*left*). Zones with parking constraints (*right*).

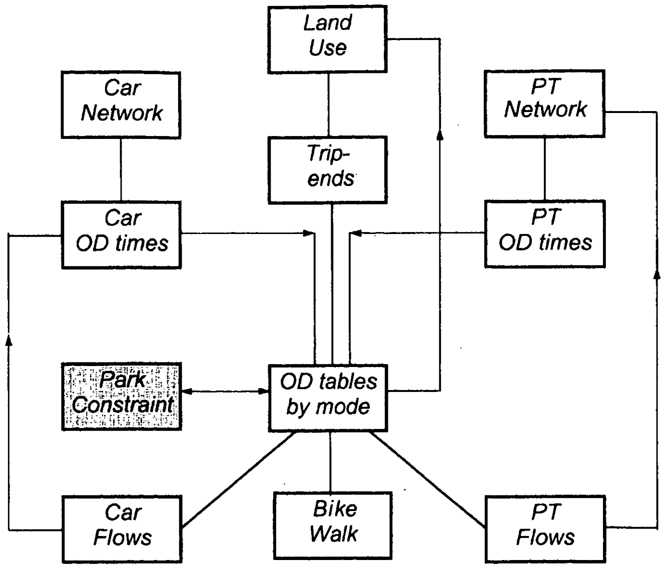

FIGURE 2 Software structure of the transportation and land use model TFTP.

model to analyze the problem being discussed after the parking restrictions are added.

Growth Vector for Distribution, Mode Choice, and Land Use

From the existing spatial distribution the growth vector changes are determined (Figure 3). An earlier paper describes in more detail how trip distribution and mode choice are calculated in conjunction with spatial development (*3*). The number of future jobs in zone i ($\Sigma_j T^f_{ij}$) is the weighted sum of the number of jobs in the base year ($\Sigma_j T^b_{ij}$) and the growth vector ($\Sigma_j T_{ij}$)

$$\left(\sum_j T^f_{ij}\right) = (1-\alpha)\left(\sum_j T^b_{ij}\right) + (\beta+\alpha)\left(\sum_j T_{ij}\right) \quad (1)$$

and the number of workers in zone j is

$$\left(\sum_i T^f_{ij}\right) = (1-\alpha)\left(\sum_i T^b_{ij}\right) + (\beta+\alpha)\left(\sum_i T_{ij}\right) \quad (2)$$

where

α = the replacement rate for real estate in the period between the base and future years, and
β = the growth in the number of workers between the base and future years.

Although the analysis can be carried out for any reasonable time period, this study used p.m. peak-period data. The growth vector is formulated as

$$T_{ij} = \rho l_i E_i m_j W_j F_{ij} \quad (3)$$

$$\sum_j T_{ij} = l_i^{-g} E_i \qquad \forall i \quad (4)$$

$$\sum_i T_{ij} = m_j^{-h} W_i \qquad \forall j \quad (5)$$

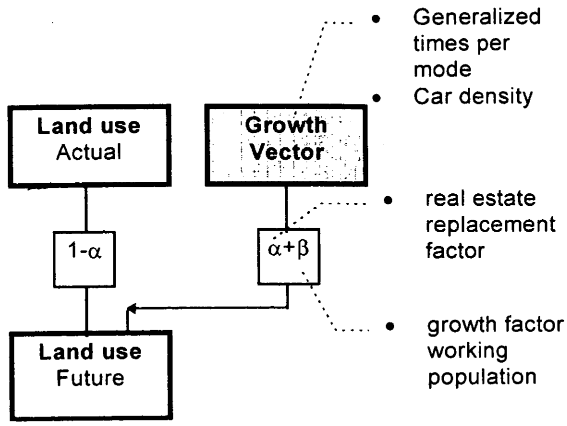

FIGURE 3 Growth vector in the dynamic land use and transportation model.

$$F_{ij} = \psi \sum_m F^{CA}_{ijm} + (1-\psi)\sum_m F^{NCA}_{ijm} \quad (6)$$

where

T_{ij} = the number of trips from zone i to zone j;
F_{ij} = the deterrence function value for trips from i to j;
E_i, W_j = employment in i (the work end) and workers in j (the home end), if the influence of the transport system is neglected;
l_i, m_j = balancing factors for origin zone i and destination zone j;
ρ, g, h = coefficients;
F^{CA}_{ijm}, F^{NCA}_{ijm} = deterrence functions for trip from i to j and mode m for persons with car available (CA) or no car available (NCA); and
ψ = cars per adult.

The deterrence function for auto trips in the car-available group is the lognormal function

$$F^{CA}_{ija} = e^{-\alpha[\log(c_{ija}+1)]^2} \quad (7)$$

where

F^{CA}_{ija} = deterrence function from i to j for auto drivers (a) among those persons who have a car available; and
c_{ija} = generalized time or cost for trips by auto.

For other modes and for the NCA group, the formulas are similar.

The mode choice has been calculated in the absence of any parking supply restrictions. The results of the "no parking restrictions" case are expressed in numbers of trip ends in the network. They are compared in Figure 4 with the Dutch National Travel Survey (OVG) data. Fifty-five percent of the trips are made by car; walkers and cyclists together account for about 40 percent of the total trips. The mode share of public transit is about 5 percent.

The Parking Constraint

There are two spatial scenarios to consider.

- Scenario 1. The spatial distribution of land use cannot change under the influence of the ABC parking policy. Fixed constraints can be used in the model.

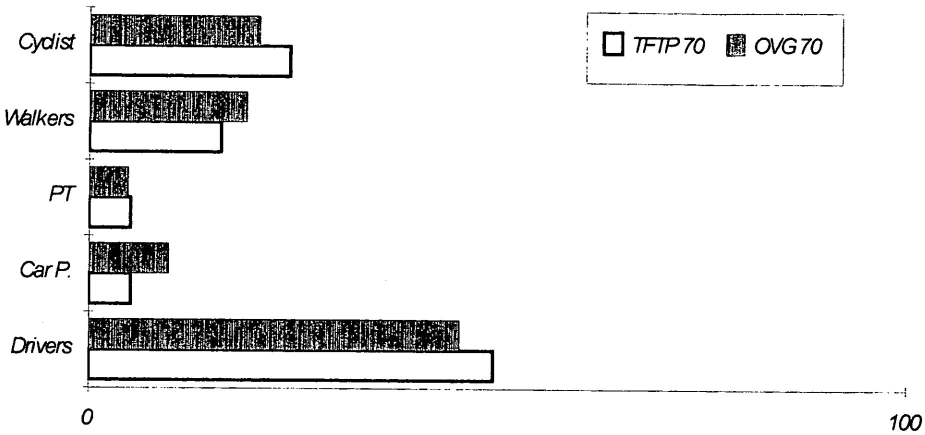

FIGURE 4 Mode choice calculated with TFTP compared with data from the Dutch national traffic survey at the 0.7 car/adult level.

- Scenario 2. The spatial distribution can change under the influence of the ABC parking policy. Elastic constraints must be introduced into the model.

The number of autos in any zone i is calculated using

$$\sum_j T_{ija} = \sum_j \rho I_i E_i m_j W_j F_{ija} = T_{i*a} \quad (8)$$

In A and B zones under the ABC parking policy restrictions, a parking supply constraint (P_i) must be added. As demand for parking places (T_{i*a}) in a particular zone becomes larger than the available number of places ($T_{i*a} > P_i$), a correction is needed so that $T_{i*a} = P_i$. For any zone subject to this parking supply constraint, its deterrence function is modified (using a parameter $0 < \eta_i \leq 1$) to reflect the added "cost" of having limited parking. For example, the deterrence function for auto trips in the car-available group is

$$F^{CA}_{ija} = \eta_i e^{-\alpha[\log(c_{ija}+1)]^2} \quad (9)$$

The subsequent increase in the generalized cost of car travel to zones with parking restrictions has a natural influence on mode choice, destination choice, and spatial development. While the first two (short-term traveler responses) have been studied before, the extent to which spatial development (longer-term developer decisions) is influenced by a particular location or parking policy has received little attention. In this paper, parking restrictions consist of a limit on spaces available. Higher parking charges, or a combination of limited supply and higher charges, could be incorporated into TFTP's generalized cost formulation.

Zone j's parking supply constraint is the zone's employment total ($\Sigma_j T_{ij}$) multiplied by 0.1 (in A locations) or 0.2 (in B locations), with overflow to adjacent residential zones ($\Sigma_j T_{ji}$), if such an overflow is permitted. There are two cases to be considered:

$$P_i = \mu\sum_j T_{ij} + \nu\sum_j T_{ji} \quad (10)$$

where $\mu = 0.1$ in A locations and $\mu = 0.2$ in B locations.

Whether the parking policy succeeds depends on the effects of any parking overflow.

- Assumption 1. A large overflow of parking demand into adjacent zones exists: $\nu = 0.5$.

- Assumption 2. Just a small overflow is presumed. The calculations for this overflow assumption are carried out in combination with spatial Scenarios 1 and 2: $\nu = 0.08$.

CALCULATIONS FOR SCENARIOS

The calculations of changes in existing spatial distribution were carried out with the growth mode contained in TFTP. The calculations are performed with an auto ownership ratio of 0.7 cars per adult, as is expected in the Netherlands.

$$\text{Radius outer circle} \approx \sqrt{\max\left(\sum_j T_{ij}, \sum_j T_{ji}\right)} \quad (11)$$

$$\text{Radius inner circle} \approx \sqrt{\text{abs}\left(\sum_j T_{ij} - \sum_j T_{ji}\right)} \quad (12)$$

If $\sum_j T_{ij} > \sum_j T_{ji}$, zone i is a working area.

No Parking Restrictions

The expected pattern of land-use development in the absence of any parking supply restrictions is shown in Figure 5. The darker-shaded inner circles indicate areas of predominately residential growth, while the lighter-shaded areas represent growth primarily in employment activity. The size of each outer circle in Figure 5 indicates the relative magnitude of the growth rates of the dominant activity. The size of the inner circle pertains to the less dominant activity's growth. The circles in Figure 5 indicate how existing land use will evolve under current accessibility conditions, in the absence of any other factors. Note that employment growth is greatest in Figure 1b where the A and B locations are shown. The results of the "no parking restrictions" case, expressed in numbers of trip ends in the network, are provided in the "No" column of Table 1. Travel mode choice and trip distribution results agree roughly with predictions for the car available group, based on Dutch National Travel (OVG) data. These values, which form the base case against which any scenario and assumption can be compared, will be placed in the "No" column of each subsequent table in this paper. To simplify these comparisons, the total number of trips made in the network will be held constant (subject to rounding errors).

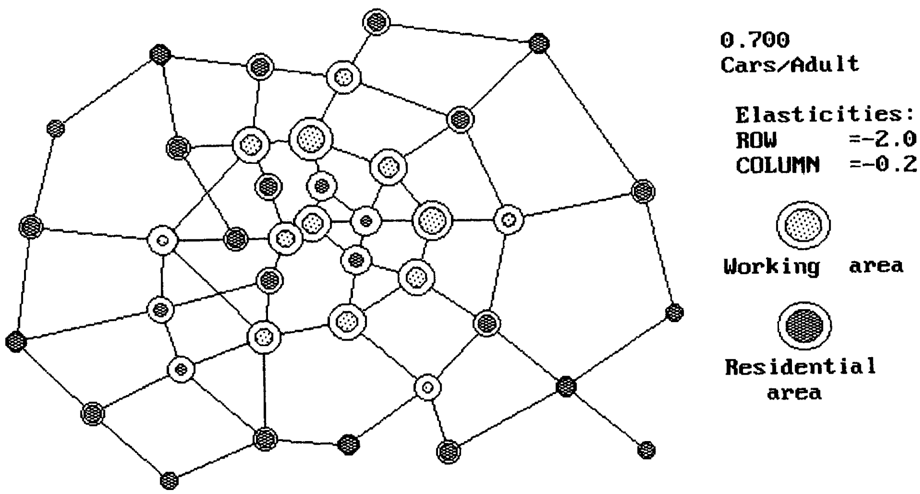

FIGURE 5 Growth vector of land use without parking restrictions.

TABLE 1 Large Overflow to Adjacent Zones

Constraints	No	Fixed	Fixed-No	%	Elastic	Elastic-No	%
Car drivers	240015	239882	-133	100	237686	-2329	99
Car passengers	24477	24463	-14	100	24265	-212	99
PT Passengers	24203	24379	176	101	22610	-1593	93
Walkers	77802	77759	-43	100	80525	2723	103
Cyclist	118635	118799	164	100	120358	1723	101
Interzonal trips	485132	485282	150	100	485444	312	100
Intrazonal trips	73839	73885	46	100	73526	-313	100
Total	558971	559167	196	100	558970	-1	100

Large Overflow to Adjacent Zones

In the first overflow case, it is assumed that a large overflow of parking demand to adjacent zones can occur. If the parking supply restrictions have no influence on the spatial distribution (fixed land use constraints, or the column labeled "Fixed" in Table 1), the changes are less than 1 percent for any mode.

Under the large overflow assumption and the scenario that spatial development does change (elastic constraints), employment shifts away from zones with parking restrictions. By comparing the half-circle of seven employment zones just north, east, and south of the network's center in Figure 5 with the same zones in Figure 6, for example, it can be observed that employment growth is lower in zones with parking restrictions [see also Figure 1 (*bottom*)] and greater in zones without parking restrictions. While networkwide auto use declines (by 2,329 + 212 = 2,541 trips in Table 1), so does public transportation ridership (by 1,593). The parking restrictions eventually lead to (if land use policy allows or can be circumvented) a decentralization of employment centers. In the Netherlands, this would favor greater use of walking (by 2,723 trips) and bicycles (by 1,723 trips) but makes public transit less practical to provide and to use.

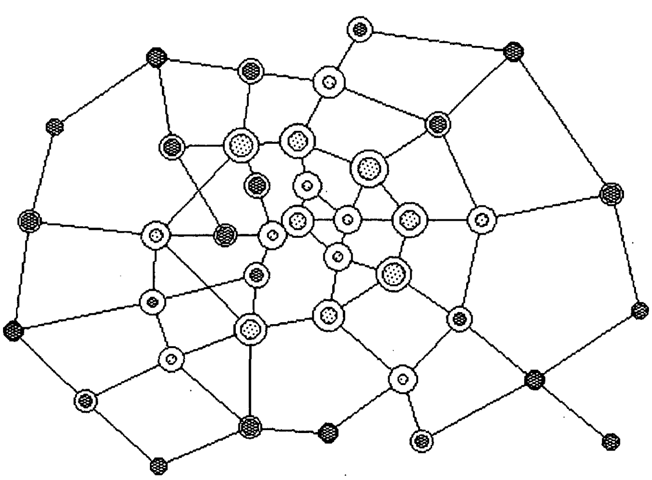

FIGURE 6 Growth vector of land use with a large overflow to adjacent zones.

Small Overflow to Adjacent Zones

In the second overflow assumption, parking policy (and enforcement) allows only a small amount of overflow of parking into adjacent zones. If spatial distribution is not affected by restrictive parking policy (Scenario 1: fixed constraints), then transit, bicycling, and walking take trips away from the automobile (see Table 2.) In other words, strong parking policy and strong land use controls—both strictly enforced—can lead to higher transit ridership.

If spatial development can change (Scenario 2: elastic constraints), trips to workplaces switch from zones with parking restrictions to other zones. If parking "costs" become prohibitive, but businesses can relocate, they will relocate, according to the model. As Figure 7 illustrates, employment growth within the original A and

TABLE 2 Small Overflow to Adjacent Zones

Constraints	No	Fixed	Fixed-No	%	Elastic	Elastic-No	%
Car drivers	240015	221533	-18482	92	235414	-4601	98
Car passengers	24477	22618	-1859	92	24116	-361	99
PT Passengers	24203	29818	5615	123	13810	-10393	57
Walkers	77802	81864	4062	105	87120	9318	112
Cyclist	118635	129880	11245	109	121954	3319	103
Interzonal trips	485132	485713	581	100	482414	-2718	99
Intrazonal trips	73839	72699	-1140	98	76671	2832	104
Total	558971	558412	-559	100	559085	114	100

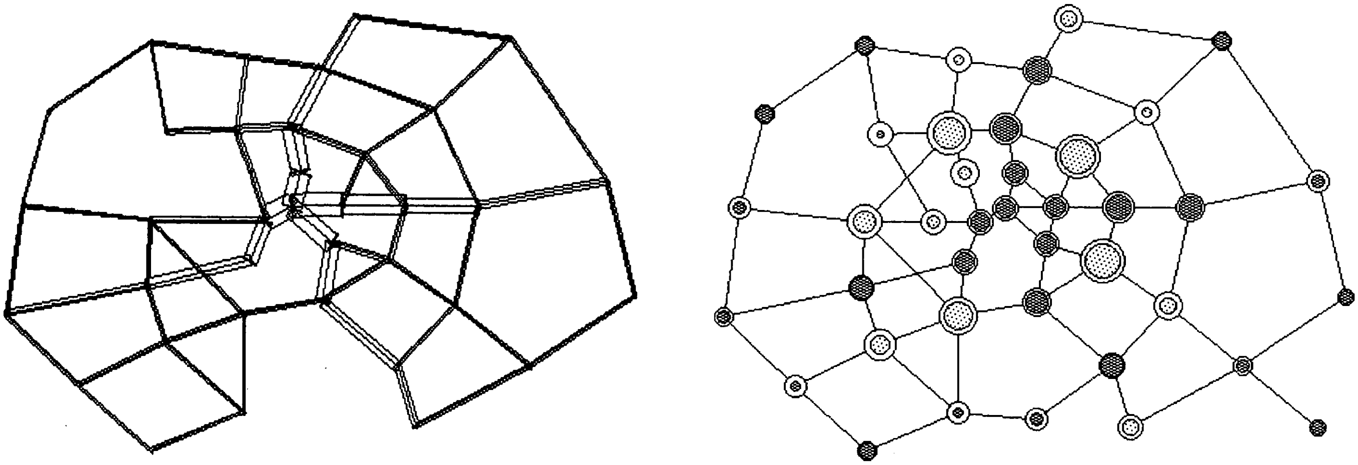

FIGURE 7 Growth vector of land use with a small overflow to adjacent zones.

B zones comes to a virtual standstill but does very well in adjacent zones without such restrictions. The results indicate a loss of almost half the original networkwide transit ridership in favor of walking and bicycling, with auto use affected very little. At the same time, less concentrated land use seems to permit some more intrazonal trips, consistent with a trend to shorter trips that are conducive to walking and cycling modes.

CONCLUSIONS

When calculating the influence of parking policy on travel patterns, attention is usually focused on mode choice. However, factors important enough to influence mode choice may also influence destination choice. If parking policy measures make certain destination choices less desirable, pressures can build to change locations of employment centers.

A stringent parking policy without consideration of its effects on land use development may have little influence on auto use and may lead to a considerable decline in public transit use (Figure 8). The desired reduction in automobile traffic, therefore, always depends on a parking policy coordinated with a location policy.

This philosophy is also valid for shopping and recreational trip purposes. The results of our study demonstrate a tendency for stringent central-city parking restrictions to strengthen pressures to decentralize urban development. If this is allowed to happen, the dispersion of transit demand will have adverse consequences for transit operations. In the Netherlands, where land use controls are traditionally strong, it may be possible to implement a parking policy that will benefit public transportation, but only if the impacts of a proposed set of policies can be anticipated. In the United States, with its looser land use controls and few areas where transit competes well with the automobile, any policy proposals designed to influence mode choice must also be thoroughly evaluated.

Using the spatial allocation model in TFTP permits insights into the relationships between a specific transportation strategy, traveler mode choice, and land use location decisions. These relationships can have important consequences for any area that wants to preserve the viability of existing transit or improve the chances for new transit service responding to changes in land use patterns.

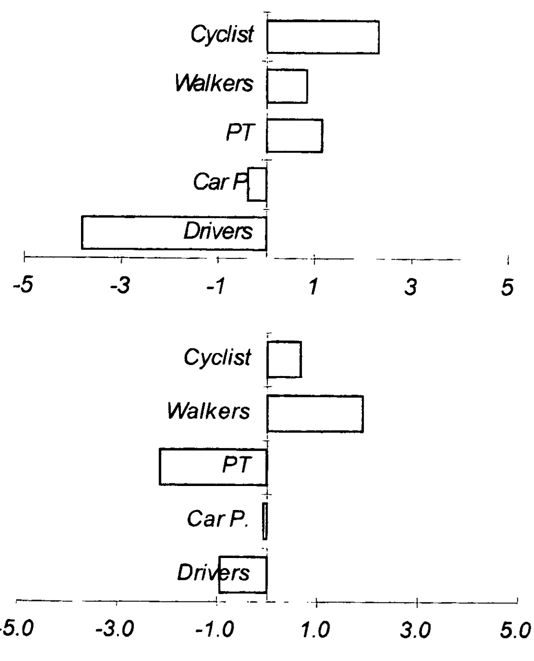

FIGURE 8 Differences in mode choice between a successful ABC policy and "do nothing" policy (*top*). Differences in mode choice with a less effective land use control and "do nothing" policy (*bottom*).

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Transportation Sketch Planning with Land Use Inputs

MARY R. LUPA, DEAN B. ENGLUND, DAVID E. BOYCE, AND MAYA R. TATINENI

As a result of the 1990 Clean Air Act Amendments, greater attention is being focused on the regional land use policies available for mitigating congestion and reducing the total vehicle miles of travel. Land use changes are made using trip origins and destination flows from a sketch-planning network of the northeastern Illinois region and tested using a combined model of travel choice. Five general scenarios are considered: dense corridors, dense clusters, growth boundaries, urban infill, and a suburb-to-suburb rail project. The results indicate that compact patterns of regional densities for residence and employment with or without transit enhancements decrease many of the results related to vehicle miles traveled. Future work with sketch networks and the combined model will involve link pricing, regional economic analyses, and air quality modeling.

As a result of the 1990 Clean Air Act Amendments, greater attention is being focused on the regional land-use policies available for mitigating congestion and reducing the total vehicle miles of travel. In this report, a preliminary analysis is performed in which land-use changes are made in an existing base of travel demand and the outputs examined. The land-use changes consist of additions and subtractions to zonal origin and destination trip end flows, which simulate the addition or removal of residences and employment to and from the zone. The five scenarios considered are described below. The data used for the analysis reported here are for 1980 for the Chicago region. A sketch-planning or aggregated zone system and network were used in the analysis with 317 zones; the Illinois zones are indicated in Figure 1. The highway network has 2,902 links; the transit network is represented by a fixed matrix of travel times and fares. Each of the five scenarios is a "slice" of the same 1,194,983 peak-hour trip origins and destination flows that existed in 1980. The knowledge gained from analyzing these scenarios is applicable to current land-use and transportation planning problems.

The first formulation of a combined model was made in 1956 by Beckmann et al. (*1*) about the same time that the sequential procedure was first conceived. This kind of formulation was specialized for the trip distribution model being used in the sequential procedure in 1973 by Evans (*2*). Evans proposed an algorithm for solving the model as well as proving that the solution does converge to the desired conditions previously outlined. A combined model—including trip distribution, mode, and route choice—was first implemented on a network of realistic size for the Chicago region by Boyce et al. (*3*) in 1982. The development and implementation of similar models for the northeastern Illinois region based on a sketch-planning network and zone system have been the subject of ongoing research involving the staff and faculty of the University of Illinois at Chicago and the Chicago Area Transportation Study. The present paper is an extension of a report by Boyce et al. (*4*) [see also Boyce et al. (*5*) and Tatineni et al. (*6*)].

The sketch or aggregated planning approach does not include a trip-generation step at this time. Auto ownership is assumed and auto occupancy is a fixed parameter. Travelers' behavior is cost minimizing. As a result, this analysis sets up an abstract travel demand problem and solves it without addressing the intricacies of residential choice theory, trip rates or trip types as functions of population density, nonmotorized travel, and the many other model components that might be desired. However, within the bounds of this abstract approach, a starting point for study, as well as reasonable results, is found.

Because the Clean Air Act of 1990 served as a catalyst for this study, a rating of the air quality impacts of each scenario might be expected. A rough measure of these impacts is provided by examining the total vehicle miles traveled and the total congested vehicle miles traveled (VMT). Future work with the sketch-planning models may include analysis of loaded link volumes and the resulting estimates of auto pollutants.

It is the intent of the authors, although not in this report, to discuss at length the notion of scale in zonal structure and in networks. The aggregated scale of sketch planning was necessary in 1975 when it was first formulated because the smaller dimensions of its components reduced both computing time and expense. Now aggregation and the resulting loss of detail may be too high a price to pay. For example, many of the details of access to transit, that is, the increase in the number of walk trips to transit as a result of transit-oriented development, are lost in the zonal averages that provide transit access characteristics in the current sketch-planning model.

The land-use scenarios in this analysis were solved on a Sun SPARCstation 10 with 64 megabytes of memory at the Chicago Area Transportation Study. Solving the model at CATS for 20 iterations takes 45 minutes, that is, 2.5 minutes per iteration.

DESCRIPTION OF SCENARIOS

These five scenarios were set up to look at the following questions: (a) Do regional growth boundaries reduce total VMT? (b) Does an imposed density of abstract households and/or employment affect total VMT? (c) How does the imposition of dense corridors compare with that of dense nodes? How does the location of the area to be densified (i.e., urban versus suburban or central versus peripheral) affect the result? (d) How do VMT reductions compare in scenarios with and without a related transit improvement?

The percentage of origin and destination trip ends that were relocated is presented in Table 1. It should be noted that the percentage of trip origins and destinations moved to create each scenario is very small. Relatively sparse suburban zones most often served as the study zones from which a proportion of trip ends was subtracted.

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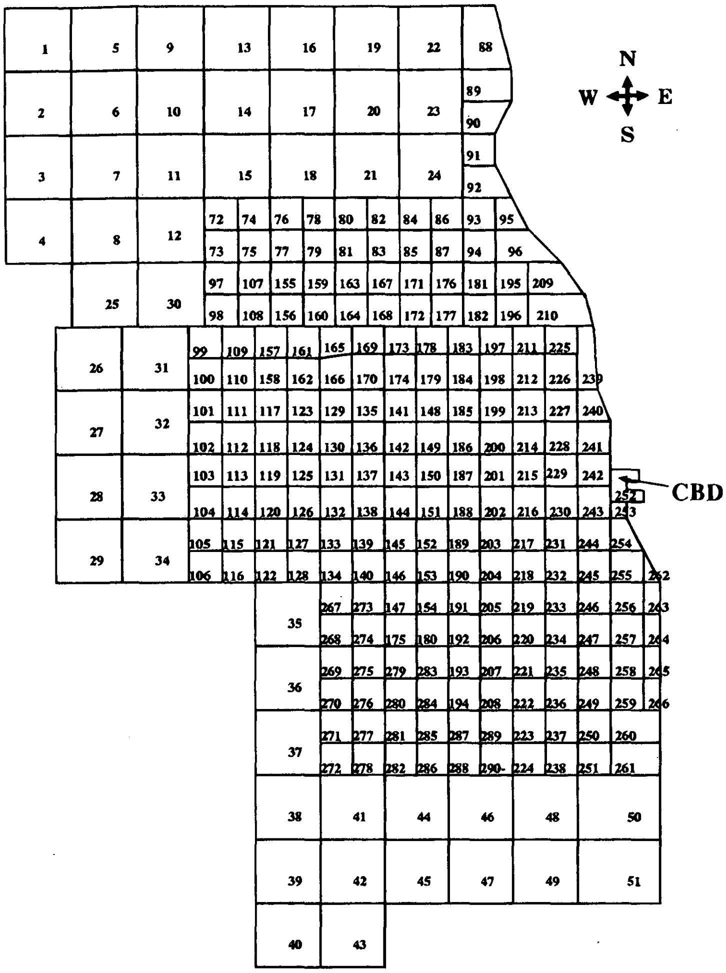

FIGURE 1 Sketch-planning study zones.

Five land-use scenarios are represented:

- A regional corridor development scenario;
- A dense regional center scenario;
- A regional growth boundary scenario using as target zones three dense suburban centers, "edge cities," in the region;
- A regional growth boundary scenario comparing the allocation of trips with an urban zone and a far suburban zone; and
- A regional growth boundary scenario using as target zones three dense suburban centers, edge cities, connected by suburb-to-suburb rail.

Regional Corridor Development, the Finger Plan

The concept of the "finger" plan is that growth be encouraged to locate in fairly narrow corridors along the existing commuter lines radiating from Chicago (see Figure 2). Major expressways would lie in the corridors as well, with regional centers of activity spaced at intervals close to transportation. The spaces or wedges between the corridors would be reserved for estate-type housing, parks, and forest preserves. The goal of this pattern of development is to plan for transportation, employment centers, open space, industry, residential communities, and natural resources by designating certain corridors for intense development and the interstices for no development (*7*).

Dense Regional Centers

A regional center is a large-scale area of concentrated development often 160 acres (64.78 hectares) or larger, characterized by a diversified mix of mutually supportive land uses, including substantial percentages of employment and housing. It has a unique character and a well-developed internal transportation system (*8*). Ten such centers were chosen for analysis in a single scenario: Crystal Lake, Waukegan, Lake-Cook Road corridor, Aurora, Elgin, Glen Ellyn, Oak Park–Austin, Ford City, Matteson, and Joliet. These centers are spread geographically around the region (see Figure 3). Most of the zones have some transit service and good access to the highway network. The goal of this pattern of development is to enhance transportation efficiency.

Regional Growth Boundary With Dense Suburban Centers (Edge Cities)

An "edge city" is defined as having (a) 5 million ft^2 (464,684 m^2) or more of leasable office space; (b) 6,000 ft^2 (558 m^2) or more of retail space; (c) a population that increases at 9 a.m. on workdays, marking the location as primarily a work center, not a residential suburb; (d) a local perception as a single end destination for mixed use; and (e) a history—30 years ago—in which the site was by no means

TABLE 1 Percentage of Regional Trip Ends Relocated for Land Use Scenarios

Scenario	% origins relocated	% destinations relocated
Finger plan	3.366	2.618
Regional centers	3.162	2.890
Growth boundaries		
1 tier	0.0027	0.0034
2 tier	0.0088	0.0070
Growth boundary		
Urban center	0.0027	0.0034
Far suburban center	0.0027	0.0034
Growth boundary with "Edge Cities" and rail	0.0027	0.0034

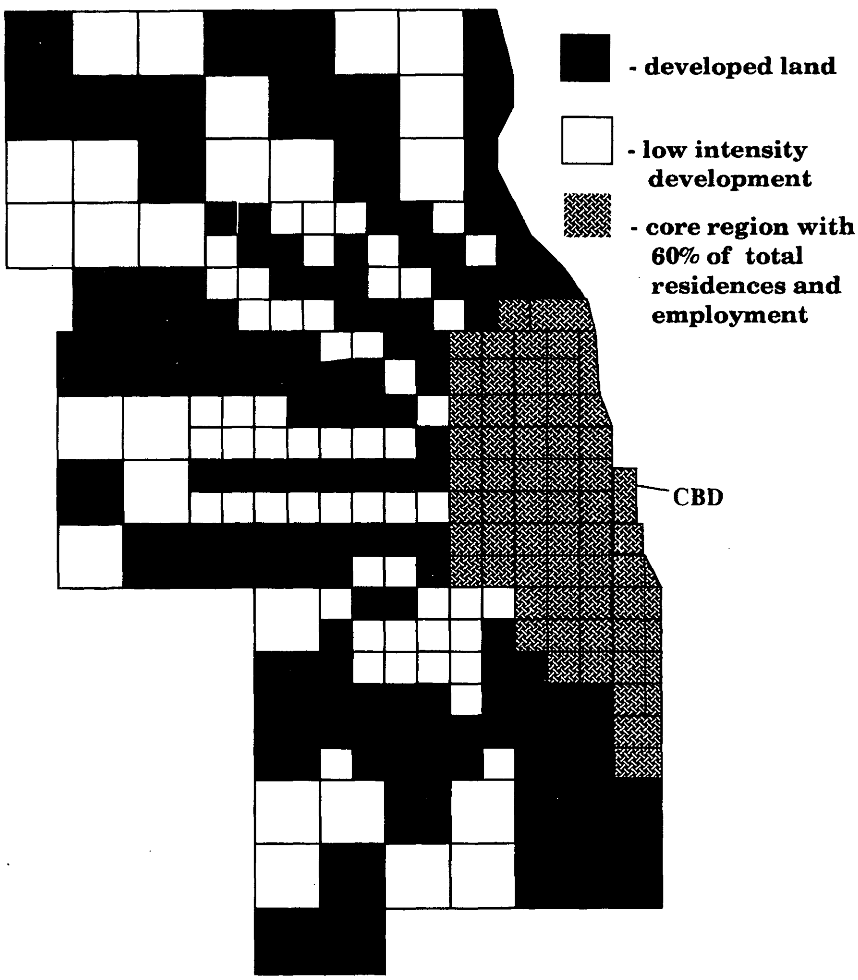

FIGURE 2 Coding scheme for regional corridor development.

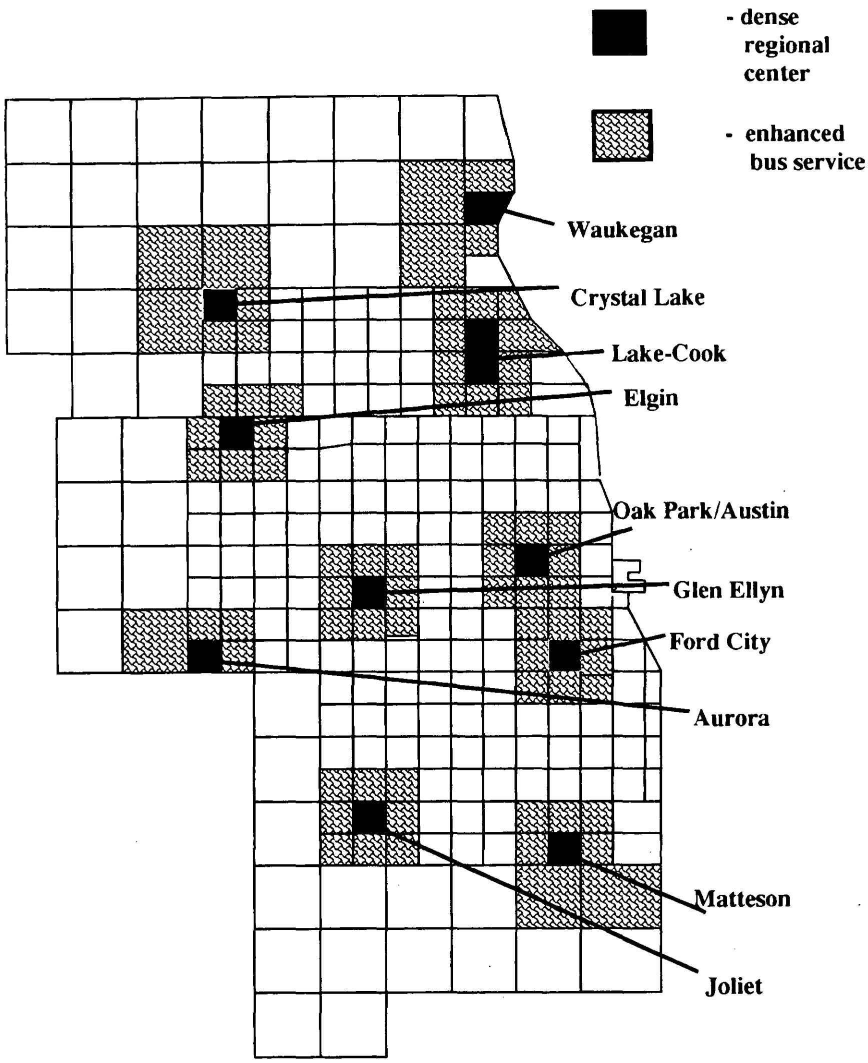

FIGURE 3 Dense regional centers.

urban but was overwhelmingly residential or rural in character. The region has five of these edge cities: (a) the central business district (CBD); (b) the Schaumburg area, including the Woodfield Mall; (c) the O'Hare Airport area; (d) the Illinois research and development corridor, including the area around Oak Brook, Lisle, Naperville, Aurora, and the East-West Tollway; and (e) the Lake-Cook corridor, around the Edens Expressway and the Tri-State Tollway (*9*). These edge city zones differ from the 10 regional centers in that they have densified naturally with the highway and transit access that accompanies or precedes development. We examine the results of further intensifying three of them—the Lake-Cook area, the Schaumburg area, and the Naperville area—using a growth boundary to gather origin and destination trip ends. This scenario was run using first one tier of peripheral zones and then two tiers (see Figure 4).

Regional Growth Boundary With a Comparison Between Urban Infill and Far Suburban Infill

In this scenario, the one-tier urban growth boundary described previously is activated and the resulting origin and destination trip ends applied first to an urban and then to a far suburban zone. The goal is to compare the results of applying densification in two very different locales. The highway network remained constant; identical enhanced bus service was provided to each infill zone in turn. This scenario is depicted in Figure 5.

Regional Growth Boundary With Dense Suburban Centers (Edge Cities) and a Rail Project

In this scenario, the edge city zones used before are connected by a premium service commuter rail that corresponds to the middle circumferential commuter rail project in the Chicago Area Transportation Study regional plan for 2010 (*10*). The right-of-way for the rail is Lake-Cook Road and the existing Illinois 53 right-of-way owned by the Illinois Department of Transportation (*11*). Because of its circumferential route, this proposed railway would provide transfers to and from the CBD via five existing Metra commuter lines. (See Figure 6.)

The bus and rail service that was included in two scenarios is designed to replicate the base service characteristics of local bus and

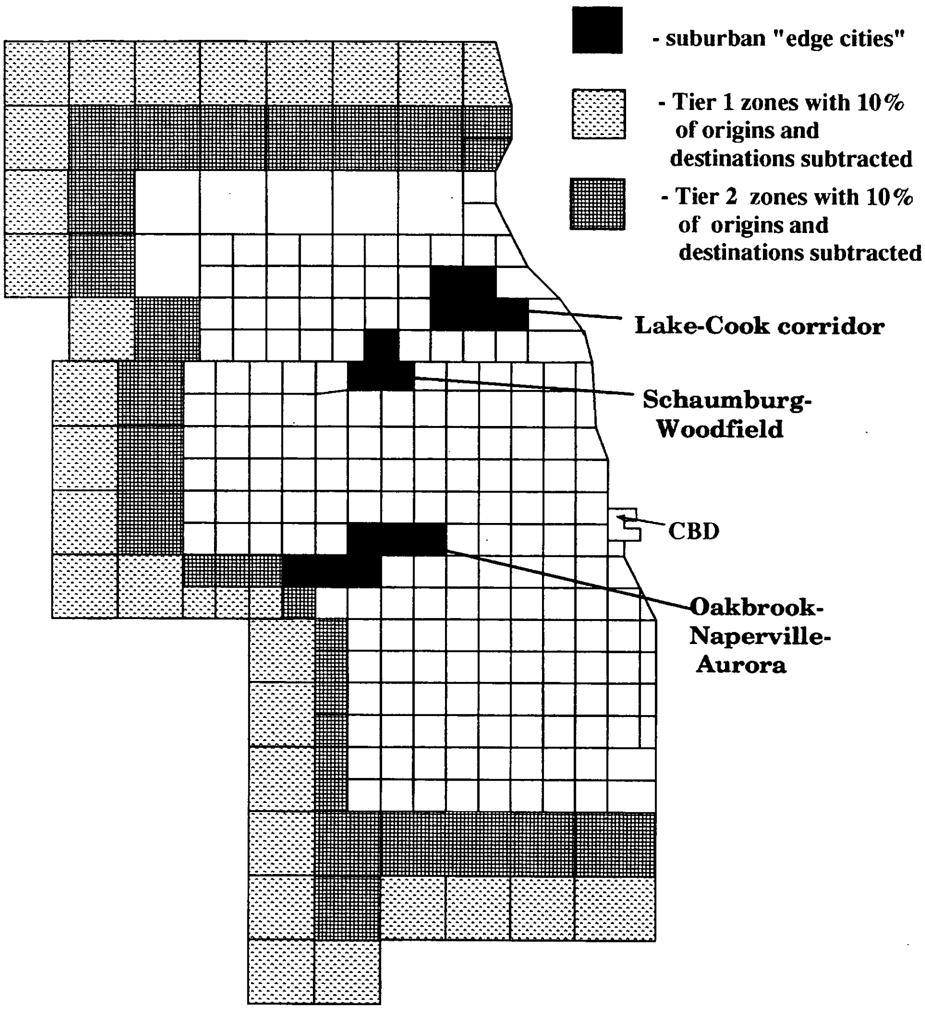

FIGURE 4 Regional growth boundary with "edge city."

premium rail as they exist in the northeastern Illinois region. Cost analyses from the point of view of the transit service provider will not be provided.

OUTPUTS FOR ANALYSIS

Six measures are selected to evaluate each scenario: mode choice, mean trip length, total and congested vehicle miles of travel, mean travel time, and mean generalized cost of travel. Highway costs are a weighted sum of the operating cost on the link as a function of flow, parking in each egress zone, walk time in each access zone, auto occupancy factor, and a fixed auto travel cost. Transit costs are a weighted sum of the transit in-vehicle time, transit fare, transit out-of-vehicle time, and a transit bias coefficient. Congested vehicle miles are the total vehicle miles on all links with flow exceeding capacity.

EFFECT OF REGIONAL CORRIDOR DEVELOPMENT

According to the original finger plan, the part of the region lying roughly in Cook County should ideally account for 60 percent of the residences and employment in the region. The remaining 40 percent would be divided into fingers (regional corridors) and interstices, the largely empty space between the fingers. Metra rail service and major highways would define the fingers. The sketch network zonal values were examined. The 1980 data showed that an approximate 60–40 split between Cook County and non-Cook counties was indeed the case. So the finger land-use scheme was constructed by removing all trip ends from the non-Cook interstices and adding them proportionately to the fingers. The results of assuming a regional corridor development plan on each of the output variables considered are presented in Table 2 and may be summarized as follows.

Effect on Mode Choice

With the incorporation of regional corridors, transit use increases slightly. That auto is still the overwhelming choice for travel to work suggests that many work trips do not begin and end in the same regional corridor.

Effect on Trip Length

As indicated in Table 2, the incorporation of regional corridors is marked by a decrease in the average trip length for both modes, with

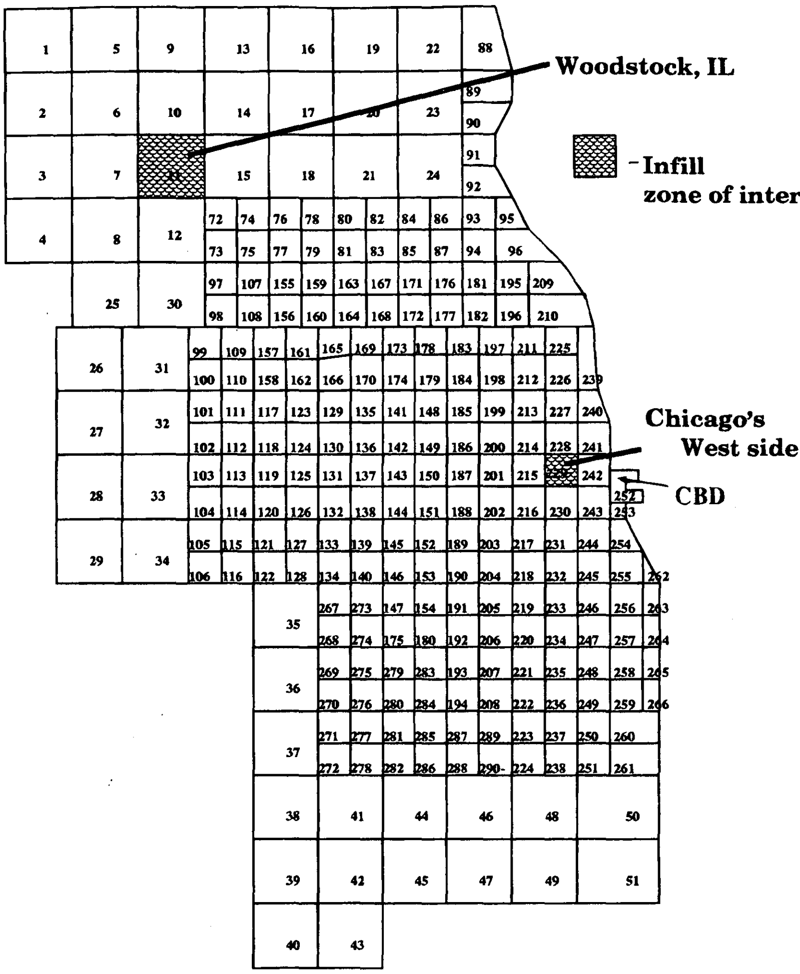

FIGURE 5 Comparison of urban versus far suburban infill.

auto showing a stronger decreasing trend. In suburban areas, the corridor zones contain virtually all of the residence and employment trip ends. The result is a rough auto-based jobs-housing balance that overall produces shorter mean trip lengths.

Effect on Travel Time

Auto travel time decreases due to an 18 percent increase in intrazonal auto trips; transit time increases slightly.

Effect on Vehicle Miles and Congested Vehicle Miles

Freeway congested vehicle miles of travel increase while total congested vehicle miles decrease. It might be expected that some highway paths combined with denser settlement patterns would increase congestion, and that this increase is exceeded by the benefits of shorter trips due to a jobs-housing balance.

Effect on Generalized Costs

The average generalized cost decreases for auto due to shorter trip lengths and times. Transit generalized cost increases slightly because of longer travel times.

EFFECT OF DEVELOPING DENSE REGIONAL CENTERS

Ten regional centers were defined (see Figure 4). To build them, 10 percent of the origin and destination trip ends were subtracted from the zones surrounding the zone of interest and added to the regional center zone. The output values were then calculated. A two-way bus that connects each surrounding zone to its regional center was added. Ten bus services were added. The buses travel at a mean speed of 12 mph (19.3 km/hr) with headways of 5 minutes and with a fare comparable to the base Chicago Transit Authority fare. The goal of adding this bus service was to link the center zone with the surrounding zones with convenient inexpensive transit service. The changes due to defining and developing these regional centers for the regional center scheme both with and without bus are presented in Table 3.

These effects may be summarized as follows.

Effect on Mode Choice

Transit use increases when the regional center zones are defined and increases again when they receive transit enhancements. That the first increase in transit use occurs when no transit projects are added indicates that population and employment density influence mode

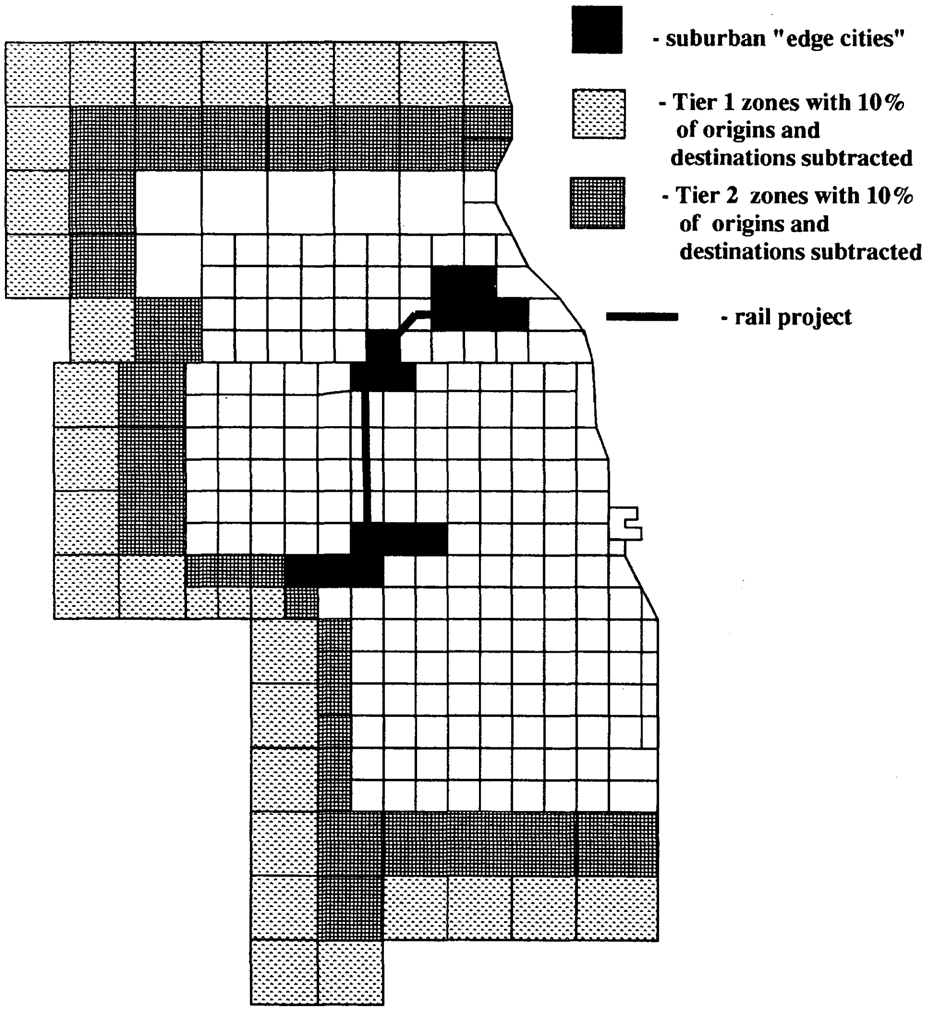

FIGURE 6 Regional growth boundary with "edge cities" and rail project.

choice. The further increase in transit use when bus service is added demonstrates that the service is well placed to serve existing and newly diverted transit work trips around the regional centers.

Effect on Trip Length

When the 10 regional centers are defined, auto trip length decreases due to the more compact nature of the region. When attractive bus service is added, however, local trip makers leave auto for transit, thus driving up the mean auto trip length. Transit trip lengths decrease when the centers alone are defined. This result stems from the addition of short transit trips to the regional mix. When the bus service is added, transit trip length increases to a value higher than in the base.

Effect on Travel Time

The logic of the mean trip length applies to the mean trip time, that is, when auto travel increases and intrazonal auto trips increase, mean auto travel times decreases. When transit increases as a mode and intrazonal transit trips decrease, mean transit travel times increase.

Effect on Vehicle Miles

Vehicle miles traveled decrease due to the more clustered placement of origins and destinations and to the increased number of travelers using transit.

Effect on Congested Vehicle Miles

Total congested vehicle miles decrease due, in part, to the reduction of total VMT. During testing of this scenario, experiments were conducted using higher percentages of trip ends removed from the surrounding zones. These experiments produced congestion hot spots since the existing highway network was unable to serve the increased use.

Effect on Generalized Cost

Generalized cost for auto decreases due to generally shorter trip lengths and times. Transit generalized cost varies due to the shifting mix of bus use.

TABLE 2 Base Versus Regional Corridor "Finger Plan"

		base	corridor
% transit in region		15.963	16.109
Mean trip length	(auto)	10.385 mi	10.143 mi
		16.71 km	16.32 km
	(transit)	9.829 mi	9.746 mi
		15.82 km	15.68 km
Mean travel time	(auto)	26.397	25.966
(minutes)	(transit)	35.227	35.260
Total vehicle miles traveled		8,240,930	8,034,712
Total vehicle kilometers traveled		13,259,656	12,927,852
Congested vehicle miles		4,313,712	4,266,326
Congested vehicle kilometers		6,940,762	6,864,518
Generalized cost	(auto)	2.908	2.866
	(transit)	4.199	4.197

TABLE 3 Base Versus Dense Regional Centers

		base	reg. center	reg. center with bus
% transit in region		15.963	16.005	16.454
Mean trip length	(auto)	10.385 mi	10.380 mi	10.392 mi
		16.710 km	16.70 km	16.72 km
	(transit)	9.829 mi	9.798 mi	10.053 mi
		15.82 km	15.77 km	16.18 km
Mean travel time	(auto)	26.397	26.385	26.400
(minutes)	(transit)	35.227	35.169	36.577
Total vehicle mi traveled		8,240,930	8,232,762	8,198,308
Total vehicle kms traveled		13,259,656	13,246,514	13,191,078
Congested vehicle miles		4,313,712	4,275,289	4,252,069
Congested vehicle kms		6,940,762	6,878,940	6,841,579
Generalized cost	(auto)	2.908	2.908	2.909
	(transit)	4.199	4.190	4.316

EFFECT OF A REGIONAL GROWTH BOUNDARY

In this scenario, two schemes are used: (a) a one-tier reduction scheme in which 10 percent of the origin and destination trip ends are subtracted proportionately from the outer periphery of the region and (b) a two-tier scheme in which the two outer rings receive the treatment (see Figure 5). In both cases, the trips are added proportionately to the three edge city zones. The effects of assuming a regional growth boundary are presented in Table 4 and summarized below.

- *Effect on mode choice:* very slight decrease in transit share for both one tier and two tiers;
- *Effect on trip length:* very slight decrease for both one tier and two tiers;
- *Effect on travel time:* slight increase in mean auto travel time and slight decrease in transit time;
- *Effect on vehicle miles:* very slight decrease for both one tier and two tiers;
- *Effect on congested vehicle miles:* increase as the trip ends are collected into three already-busy suburban zones; and
- *Effect on generalized cost:* very slight decrease for both one tier and two tiers.

The overall changes in all output variables here are very small, in part because of the tiny percentage of the regional trips that are being moved (see Table 5). The 10 percent of the zonal origins in the one-tier periphery amounted to 0.0027 percent of the region's origin trip ends, although they were in zones that represented 26.6 percent of the region's land. The 10 percent of the zonal destinations in the one-tier periphery amounted to 0.0034 percent of the region's destination trip ends and again 26.6 percent of the region's land. When two tiers of peripheral zones were used, the 10 percent of the zonal origins in the periphery amounted to 0.0088 percent of the region's origin trip ends though they were in zones that represented 45.8 percent of the region's land. The 10 percent of the zonal destinations in the two-tier periphery amounted to 0.0070 percent of the region's destination trip ends and again 45.8 percent of the region's land.

All output measures in this scenario exhibited very little change because a very small percentage of the regional trips were shifted to another zone. That these shifts are small is of less interest to many planners than their very existence.

EFFECT OF A REGIONAL GROWTH BOUNDARY WITH TRIP ENDS ADDED TO AN URBAN VERSUS A FAR SUBURBAN ZONE

In the fourth scenario, origin and destination trip ends are subtracted from one tier of the periphery and added to two zones for comparison purposes. These two zones are a city of Chicago zone that represents a 9-mi^2 section of the near West Side of Chicago and a far suburban zone that represents the 36-mi^2 containing Woodstock, Illinois (see Figure 6). Each infill zone is served by a two-way bus service of the type described in the section on regional centers. Ten percent of the trips in one tier of the peripheral zones were directed to each of these zones in turn. The goal was to compare the results

TABLE 4 Base Versus Regional Growth Boundary

		base	growth boundary 1 tier	growth boundary 2 tier
% transit in region		15.963	15.958	15.945
Mean trip length	(auto)	10.385 mi	10.379 mi	10.375 mi
		16.71 km	16.70 km	16.69 km
	(transit)	9.829 mi	9.796 mi	9.783 mi
		15.81 km	15.76 km	15.74 km
Mean travel time	(auto)	26.397	26.413	26.441
(minutes)	(transit)	35.227	35.210	35.194
Total vehicle kms traveled		13,259,656	13,252,783	13,249,784
Total vehicle mi. traveled		8,240,930	8,236,658	8,234,794
Congested vehicle mi.		4,313,712	4,327,863	4,369,272
Congested vehicle kms.		6,940,762	6,963,531	7,030,158
Generalized cost	(auto)	2.908	2.909	2.911
	(transit)	4.199	4.197	4.197

TABLE 5 Percentage of Regional Trip Ends in One- Versus Two-Tier Scenarios

	One Tier	Two Tiers
% of zonal trips removed	10	10
number of zones used	31	61
% of regional land used	26.6	45.8
% of regional trip origins removed	.0027	.0088
% of regional trip destinations removed	.0034	.0070

of encouraging residential and employment location in an urban infill zone versus a far suburban zone. The results are presented in Table 6 and discussed below.

Effect on Mode Choice

Transit percentage of regional mode split increases in both strategies with a larger increase in the urban infill scheme due to a larger population in the urban area available to use the transit service.

Effect on Trip Length

Mean auto trips length decreases in the urban scheme because of the central location of the zone and in the far suburban scheme because of the growth in intrazonal auto trips. Transit trip length decreases in both schemes due to the addition of new shorter transit trips.

Effect on Travel Time

Auto travel time generally increases due to a rise in congested miles. Mean transit time in the urban infill scheme decreases 2 percent as

TABLE 6 Base Versus Urban Infill and Far Suburban Infill

		base	urban infill	far suburban infill
% transit in region		15.963	16.125	15.956
Mean trip length	(auto)	10.385 mi	10.379 mi	10.378 mi
		16.71 km	16.70 km	16.70 km
	(transit)	9.829 mi	9.589 mi	9.797 mi
		15.82 km	15.43 km	15.76 km
Mean travel time	(auto)	26.397	26.407	26.429
(minutes)	(transit)	35.227	34.351	35.212
Total vehicle mi. traveled		8,240,930	8,220,084	8,235,778
Total vehicle kms traveled		13,259,656	13,226,115	13,251,367
Congested vehicle mi.		4,313,712	4,368,305	4,321,244
Congested vehicle kms		6,940,762	7,028,602	6,952,881
Generalized cost	(auto)	2.908	2.907	2.911
	(transit)	4.199	4.138	4.198

a result of the enhanced bus service provided to eight highly populated Chicago zones, including a part of the extended CBD.

Effect on Vehicle Miles

Vehicle miles traveled decrease in both schemes due to shorter mean auto trip and to the shift to transit.

Effect on Congested Vehicle Miles

Total congested vehicle miles on both arterials and freeways increase in both schemes with the larger increase in congestion occurring in the urban infill.

Effect on Generalized Cost

Generalized costs decrease for both modes due to slightly lower travel times.

The overall results of this scenario demonstrate that constructing a slightly more compact region is marginally more efficient when the densification takes place in an urban zone instead of a far suburban zone.

EFFECT OF A REGIONAL GROWTH BOUNDARY WITH A RAIL PROJECT

In the final scenario, origin and destination trip ends are subtracted from one tier of the periphery and added proportionately to the three edge city zones. These zones are then connected by a two-way 35-mi (56.3-km) circumferential commuter rail service with 5-minute headways and a mean speed of 45 mph (72.4 km/hr). The fare is distance based. Two-way bus service was added connecting the zones with new rail service to the zones immediately adjacent. The bus service has 5-minute headways, a mean speed of 12 mph (19.3 km/hr), and a fare equivalent to the base Chicago Transit Authority local price. The goal of modeling this somewhat abstract rail service is to examine the regional changes that occur when a very attractive transit alternative is provided.

The transit network in this combined model is a fixed set of four transit matrices. To represent transit projects, the cell values were altered manually after which a shortest path algorithm was applied to the matrix (*12*). This algorithm, which was necessary to incorporate changes in one cell to all origin-destination pairs in the network, had the effect of streamlining the base transit paths. Thus, the base results in Table 6 differ from those in the previous tables.

The effects of assuming a regional growth boundary, densifying suburban edge cities, and building a rail connecting them are presented in Table 7 and discussed below.

Effect on Mode Choice

The transit percentage of regional mode split increases as a result of the attractiveness of the rail project.

Effect on Trip Length

Auto and transit trip lengths increase. Some short suburban auto trips shift to transit due to the rail project and the enhanced bus service. Transit, however, added long trips as well, resulting in a higher mean trip length for transit.

TABLE 7 Base Versus Growth Boundary with Rail

		base	growth boundary with rail
% transit in region		17.7	18.0
Mean trip length	(auto)	10.680 mi	10.687 mi
		17.18 km	17.20 km
	(transit)	9.783 mi	9.896 mi
		15.74 km	15.92 km
Mean travel time	(auto)	27.107	27.121
(minutes)	(transit)	35.906	36.377
Total vehicle miles traveled		8,296,325	8,276,121
Total vehicle kms traveled		13,348,787	13,316,279
Congested vehicle miles		4,509,013	4,481,801
Congested vehicle kilometers		7,255,001	7,211,217
Generalized cost	(auto)	2.975	2.976
	(transit)	4.263	4.347

Effect on Travel Time

Mean auto travel time and mean transit travel time increase because trip length increases.

Effect on Vehicle Miles

Vehicle miles traveled decrease due to the shift to transit.

Effect on Congested Vehicle Miles

Congested vehicle miles decrease based on a lightening of both freeway and arterial congested miles. The rail project acts to decrease some road use. When the densification took place without a new transit alternative (Scenario 3), congested vehicle miles increased.

Effect on Generalized Cost

Generalized costs for transit increased due to longer mean travel time.

The overall results of this scenario demonstrate that constructing a slightly more compact region with well-defined edge cities connected by premium rail service will decrease many of the vehicle miles traveled related outputs under study.

CONCLUSIONS

Land use inputs do not respond in a spectacular fashion to regional modeling strategies. The result of making a significant change, like introducing regional corridors, is a minimal change in the output variables. Effecting a larger change may mean making irrational or infeasible initial assumptions. It helps to recall that it took the automobile and real estate forces 50 years to establish the land-use and transportation system operating now, which responds to the land-use changes reported here with the powerful inertia of urban sprawl. Modeling land use well suggests a travel demand approach designed to be very sensitive to change, using flexible data inputs like parking costs per zone that shift if the zone becomes denser, for instance, and with a long-term (i.e., 20 years or more) horizon.

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Time-Area Concept: Development, Meaning, and Applications

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The concept of time-area occupancy by vehicles captures in the same unit not only the quantity of ground area (or space) that is required for safe vehicle movement or for storage but the period of time for which the area is occupied as well. Another advantage of time-area measure is that it links the two usually different concepts of static and dynamic transport units (either vehicles or persons) under a common variable, the time-area that they consume. Moreover, it allows efficiency to be evaluated in terms of consumed versus available time-area. This is particularly useful in comparing different transportation modes. The history of development of this concept is reviewed; previous use had been confined to cursory analyses of modes, except for pedestrian facility operational analysis and design. Further research of this concept and its applications is presented. Some basic concepts essential to time-area calculation are explained and simple formulas for several different cases are introduced. Based on these formulas, a graphical example of the time-area consumed for a hypothetical commuter round-trip using three different modes demonstrates some of the quantitative measures and insights regarding transportation and urban land use to be gained through this approach.

The ever-increasing ground-area consumption for transportation purposes is an issue of growing importance to the economy, the ecology, and the quality of life; in densely built cities, the remaining room for facility expansion and new rights-of-way is limited, while suburbs are increasingly consuming land that has a large value in remaining undeveloped.

Conventional analytical methods of area or space consumption by various transportation modes usually deal with properties measured at a point—such as speed, volume, or density for moving vehicles and persons—from which the instantaneous space requirements can be computed. Vehicles and persons that are not moving are analyzed by measuring separately the static storage area or space required, as well as the duration of area occupancy.

Time-area is the product of the time and the area consumed by a vehicle within a chosen time frame and location. Thus, the concept of time-area captures in the same unit not only the quantity of ground area (or space) that is required for safe movement or for storage but the period of time for which the area is occupied as well. This is a logical measure in that both time and area can be equally important determinants in facility sizing and in capacity computations. For example, an automobile commuter to the central city occupies a large amount of area while driving, but only for a short period of time. The driver then parks and consumes a lesser area, but for a longer duration. The total time-area expresses the entire resource demand as one unit, typically in m^2-s. By comparison, conventional methods analyze driving and parking separately.

The concept of time-space would be similar, except that space now refers to a three-dimensional volume instead of only the projected ground area. Unfortunately, the existing literature tends to use the term time-space for the two-dimensional case as well. The term *time-space* is also found in connection with the so-called time-space diagram, which is used for plotting the synchronization of traffic signals along streets. Although this is an erroneous name (time-distance diagram being the correct one), it is in common usage and thus is reason to avoid using the term time-space.

The time-area concept has several advantages:

- It represents a common measure for evaluation of area and time consumption by any transportation unit (pedestrian, vehicle, train), rather than for each mode separately.
- It allows joint measurement of consumption by moving and stationary transport units (either vehicles or persons), that is, it unifies the two usually different concepts of static and dynamic components of a transportation system. For example, a car consumes area not only when driving but when parked, and both are important, particularly in urban settings.
- It can provide a common variable for the comparison of different transportation modes. As will be seen, it is possible to do an informative analysis of relative land use and congestion effects of the various modal combinations urban travelers can select by calculating time-area consumptions for these various options.

The time-area concept has several applications, only a few of which have been fully developed. This paper shows one involving land consumption by commuters using different modes of travel. The particular application was chosen not only because it is of interest for its own sake, but because it can be presented with few equations and should be a relatively easy introduction for explaining the concept. Before this application can be presented, a brief historical review of the time-area concept will be presented, followed by a description of elementary quantitative methods of measuring and evaluating time-area.

HISTORY OF TIME-AREA CONCEPT

Previous Literature and Applications

The time-area concept has been discussed since at least 1959, when the Union Internationale des Transports Publics (UITP) published a brochure showing the concept (*1*). The next discussion of the time-area concept was in Leibbrand's 1964 book, *Transportation and Town Planning* (2). He used typical urban speeds of pedestrians and other transportation modes, each with typical occupancies, to calculate the number of square meters occupied to maintain their motion. The next discussion was in a 1965 publication by the Town Traffic Section of the International Exhibition of Transport and

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Communications (*3*). A comparison was made of streetcars, buses, and private automobiles all traveling at the same speed of 30 km/hr, to demonstrate the large difference in space requirements per passenger between the three modes, particularly the enormous space requirement for automobile passengers. In both of these discussions, the actual reference was to instantaneous area requirements, a closely related concept to time-area that will be explained later in more detail.

Pushkarev and Zupan, in *Urban Spaces for Pedestrians* (*4*), made a tabular comparison of many modes, ranging from a bicycle to an airplane landing, with the point of showing the space consumption required per person at one assumed speed and occupancy rate reasonable for the particular mode. They did not attempt to generalize the results for a wider range of potential speeds and occupancies by making a general time-area formulation. This was, however, an early effort to portray not only differences in travel times, but also the widely disparate area consumption implied by the use of different modes.

Louis Marchand, who later became chief engineer for the Regie Autonome des Transports Parisiens, made explicit reference to the time-area concept in an interview in the French journal *Metropolis* (*5*) regarding important aspects of urban mobility. Marchand gave typical time-area values for residential storage of an automobile and a bicycle and for travel by public bus, as well as per-kilometer area consumptions by a pedestrian, bicyclist, motorist, and bus passenger. However, no formulas used for calculating these values were supplied.

In the same issue of *Metropolis* in which Marchand was interviewed, Schmider (*6*) provided a table of time-area consumptions, reproduced here as Table 1. Consumptions were evaluated for a speed considered typical for each mode, assuming a travel distance of 4 km, but for three different storage times: 2, 4, and 6 hours. Thus, this was one of the early explicit calculations of time-area consumption along a path. It showed that the automobile rider consumes far more total time-area than the bicycle rider, who consumes, interestingly, far more than the bus rider.

In an article comparing the efficiency and impact of different urban transportation modes, the French economist Jean-Marie Beauvais presented a formula for computing the time-area consumed within the city traveling 2 km and then working for 8 hours (*7*). The three mode choices compared were private motorist, bus rider, and pedestrian. Beauvais summed the time-area used in motion along city streets, as well as in storage in the case of the automobile.

Marchand wrote an unpublished paper that also provided a formula for computing time-area consumption along a path and applied it to a short fixed-distance trip of 5 km. For auto travel, parking for three different time durations was included. In addition to the three modes evaluated by Beauvais—auto driver, bus passenger, and pedestrian—Marchand included the bicycle and the Metro

TABLE 1 Time-Area Calculations by André Schmider (*6*, p. 57)

1a. Example of consumption of time-area for a 4 km round trip with variable time on-site

Speed	Mode	Time on site					
		2 hours		*4 hours*		*8 hours*	
kmph		time	m^2-h	time	m^2-h	time	m^2-h
	Bicycle:						
12	moving	1/3	6	1/3	6	1/3	6
	parked	2	3	4	6	8	12
	total	2+1/3	9	4+1/3	12	8+1/3	18
	Private auto:						
40	moving	1/10	9.6	1/10	9.6	1/10	9.6
	parked	2	16	4	32	8	64
	total	2+1/10	25.6	4+1/10	41.6	8+1/10	73.6
	Bus:						
15	moving	4/15	1.2	4/15	1.2	4/15	1.2
	parked	1/10	0.1	1/10	0.1	1/10	0.1
	total	11/30	1.3	11/30	1.3	11/30	1.3

1b. Consumption of area on a per unit basis

	Area occupied per vehicle [m^2]	No. of persons per vehicle -	Area occupied per person [m^2]	Area consumed per vehicle [m^2•h/veh-km]	Area consumed per person [m^2•h/prs-km]
Mode					
On foot	0	1	0.3	-	0.4
Bicycle	1.5	1	1.5	1.5	1.5
Auto	10	1.25	8	3	2.4
Bus	30	30	1	9	0.3

Note: Translated from the French, with terminology corrected for consistency.

(*8*). A paper similar to Marchand's 1985 paper was presented by his superior but attributed largely to him at the 1989 Congress of the UITP in Singapore (*9*).

The French analysts used the time-area concept to gain some macroeconomic policy insights regarding the future development and functionality of cities. Meanwhile, during the same years, a parallel effort was under way in the United States to develop a design and operational analysis tool for pedestrian facilities. Fruin and Benz (*10*) published the first comparison of using a time-area approach versus the conventional approach as outlined in *Transportation Research Circular 212: Interim Materials on Highway Capacity* (*11*). The basis for comparison was going to be a level of service standard for pedestrians created by Fruin in his landmark book *Pedestrian Planning and Design* (*12*). These standards are analogous to those used in the *Highway Capacity Manual* (*13*) for motor vehicle facilities.

Using aggregated average values for storage densities and times and averaged walking speeds, Fruin and Benz have shown it is possible to get very similar results regarding offered level of service to those found by using the much more complicated procedure outlined in *Circular 212*. In addition, it was easy to estimate the service offered under surge conditions, that is, when two heavy pedestrian platoon flows must bypass each other in the middle of the crossing, a design situation not accounted for in *Circular 212*. Benz (*14–16*) as well as Grigoriadou and Braaksma (*17*) have successfully enhanced and used this approach in the operational analysis of rapid transit stations.

Recent Work and Further Applications

The work reviewed can be categorized into two different types of analysis based on their goals. One goal is to use the relative time-area consumption of various modes as an indicator helpful for macroeconomic and area (space) allocation decisions where area (space) is scarce and opportunity costs are high. Yet, analyses to date had been too cursory to be able to draw many policy conclusions.

The other goal has been to develop a new method to analyze the performance of existing pedestrian facilities by an easier method than those currently in common usage and to use this method for preliminary sizing of new facilities. While providing useful results for many applications, the analysis was still coarse in the use of bulk or averaged pedestrian movement speeds and aggregate storage properties.

Significantly, the time-area approach had not been extended to other realms, such as roadway or intersection design, facility performance evaluation for vehicles running on fixed rights-of-way, a resource consumption indicator for costing and pricing, and so forth. Thus, general formulas needed to be created for computing time-area for a variety of modes under different conditions and for different analysis purposes. Furthermore, these relations would need to be evaluated under a range of conditions and presented in comparative graphical formats. Such work was done by one of the authors in his doctoral dissertation (*18*). The formulas and example applications in the remainder of this paper are distilled from this work.

BASIC DEFINITIONS AND FORMULAS

The Shadow, Braking Regime, and Module

As a vehicle moves along its right-of-way, it may be visualized as traveling with an open area attached to the front of it, an area referred to as its "shadow." The purpose of the shadow is to maintain adequate reaction and braking distance from the preceding vehicle. The shadow is regulated using one of four systems of vehicle driving and control:

- Manual, with visual control;
- Manual, with advisory signals;
- Manual, with fail-safe signals (automatic override); and
- Automated.

With manually driven vehicles, the driver must use judgment and visual control to maintain at least the minimum shadow. An example of manual driving with advisory assistance is the use of trackside signals, but the system takes no action if a signal is disregarded. With automatic override, the driver maintains the shadow, but the control system triggers automatic braking if the minimum shadow is violated. On fully automated vehicles, a computer regulates the shadow at all times.

The minimum shadow depends on the "safety regime," that is, the vehicle-following rules that determine the degree of safety offered under various circumstances. Under a manual system, the rule can be as simple as the "2-second separation" rule taught in driver education, or the obsolete "one vehicle length for every 10 mph" rule used by previous generations. Higher safety regimes consider not only speed but also the relative braking rates of the leading and following vehicles, vehicle subsystem reliability, gradients, and other factors.

The length of the shadow is a function of the vehicle-following rule being used, and, therefore, it changes continuously with the speed profile. The shadow can vary randomly among individuals and situations in the case of a manually driven mode. Figure 1 presents the important coordinates used to measure the location of a vehicle and its shadow. The key reference, x_i, marks the front of a vehicle i. x_{1i}, marks the rear of the vehicle, which is located simply at x_i minus the length of the vehicle, δ. x_{2i} marks the location of the front of the shadow. The shadow length $x_{2i} - x_i$ is a function of speed, and is therefore designated as $f(v_i)$. As the vehicle changes speed while proceeding along the path denoted by x, the shadow length changes. It is directly, but not usually linearly, proportional to speed. Therefore, when the speed is constant, the length of the shadow stays constant. When the speed drops to zero, the shadow disappears.

One more term must be defined before proceeding to equations that calculate time-area consumption. $L_i(V_i)$, defined as the sum of the vehicle length plus its shadow length, is referred to as the "module length." The area of the right-of-way occupied by the vehicle and its shadow will, in turn, be referred to as the "module," the term used by Fruin (*12*). The module may be visualized as the instantaneous area associated with or required by a vehicle for operation at a given time. Note that as the speed goes to zero, the module—or instantaneous area—decreases to the length of the vehicle times the right-of-way width, δW.

As an example, the module length of an automobile in congested flow can often be approximated fairly well using the "one vehicle length per 10 mph" car-following rule:

$$L_i(v_i) = \delta + f(v_i) = \delta + B_1 \frac{\delta}{10} v_i \qquad \text{(feet)} \tag{1}$$

where B_1 is just a conversion factor for unit consistency. But as a more general relation, one could use any speed increment, D:

$$L_i(v_i) = \delta + B_2 \frac{\delta}{D} v_i \qquad \text{(meters)} \tag{2}$$

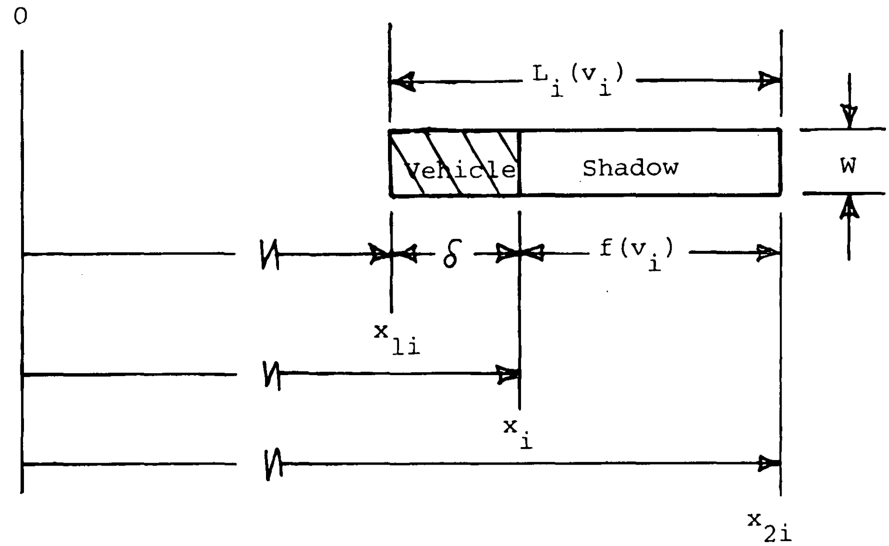


FIGURE 1 Coordinates used to locate the instantaneous area or module of a vehicle.

In the SI system, the value of D for the "10-mph increment" car-following rule would be 16.1 km/hr.

As another example, the module length for a signal-controlled rail vehicle uses a safe vehicle-following rule, that is, a distance at least equal to the stopping distance under all conditions, because it is based on physical considerations and not merely on a rule of thumb:

$$L_i(v_i) = n\delta + t_r v_i + \frac{v_i^2}{2b_2} - \frac{v_i^2}{2b_1} \quad \text{(meters)} \tag{3}$$

where $n\delta$ is the length of an n-car train; t_r is the operator reaction time; and b_1 and b_2 are the braking rates assumed for the leading and following trains, respectively. The module, M, then follows as the product of the right-of-way width and the module length:

$$M = WL_i(v_i) \tag{4}$$

The braking rates selected depend on the stringency of the safety regime. The highest regime, designated "A," provides that the following vehicle can stop safely even if the leading vehicle hits a brick wall. Regimes B and C provide somewhat less protection, and therefore can have shorter shadow lengths. [See the text by Vuchic (*19*) for further elaboration.] Figure 2 illustrates module versus speed for three different sizes of rolling stock using typical values for operator reaction time and for braking rates. As train length gets longer, the module can be visualized to shift upward, and the train itself becomes an increasingly large fraction of the module. The effect of the more stringent operating regime is to make the module rise more steeply as speed increases.

Since vehicles do not generally run at the precise module required by the safety regime at which they try to operate, a stream of vehicles can be represented by an average value, analogous to conventional flow-based models.

Time-Area Consumption for a Continuous Stream of Vehicles Moving at Constant Speed

The derivations of precise formulas for time-area consumption under general conditions are lengthy and complex and cannot be presented here. Complexities include treatment of vehicles as either discrete or continuous flows depending upon traffic conditions, physical characteristics of vehicles, rights-of-way involving curves, intersections, and boundary conditions where vehicles pass into or out of the area being analyzed. However, under conditions of uninterrupted moderate to heavy flow of vehicles that is maintaining a constant speed, calculation is straightforward. T is the duration of the analysis period, while A is the analysis area, in most cases a length of right-of-way S with width W. Q is the flow of vehicles into (and out of) the analysis area during the analysis period. The average time-area consumed by each vehicle i is then

$$\overline{TA_i} = \frac{TA}{Q} = \frac{TWS}{Q} \quad \left(\frac{\text{m}^2\text{-s}}{\text{vehicle}}\right) \tag{5}$$

In words, it is the total available time-area divided by the flow. Under the current assumption of uninterrupted constant rate flow, T can be eliminated by using the relation

$$Q = qT \quad \text{(vehicles)} \tag{6}$$

where q is the flow rate expressed in vehicles per hour. Thus,

$$\overline{TA_i} = \frac{TWS}{Q} = \frac{TWS}{qT} = \frac{WS}{q} \quad \left(\frac{\text{m}^2\text{-s}}{\text{vehicle}}\right) \tag{7}$$

But q can also be expressed as the product of constant traffic density, k, and speed, v:

$$\overline{TA_i} = \frac{WS}{kv} \quad \left(\frac{\text{m}^2\text{-s}}{\text{vehicle}}\right) \tag{8}$$

This is a convenient substitution because the inverse of density is spacing, which is also the module length under the present assumptions, so that the previous equation can be rewritten:

$$\overline{TA_i} = WS\,\frac{L_i(v_i)}{v} = \frac{MS}{v} \quad \left(\frac{\text{m}^2\text{-s}}{\text{vehicle}}\right) \tag{9}$$

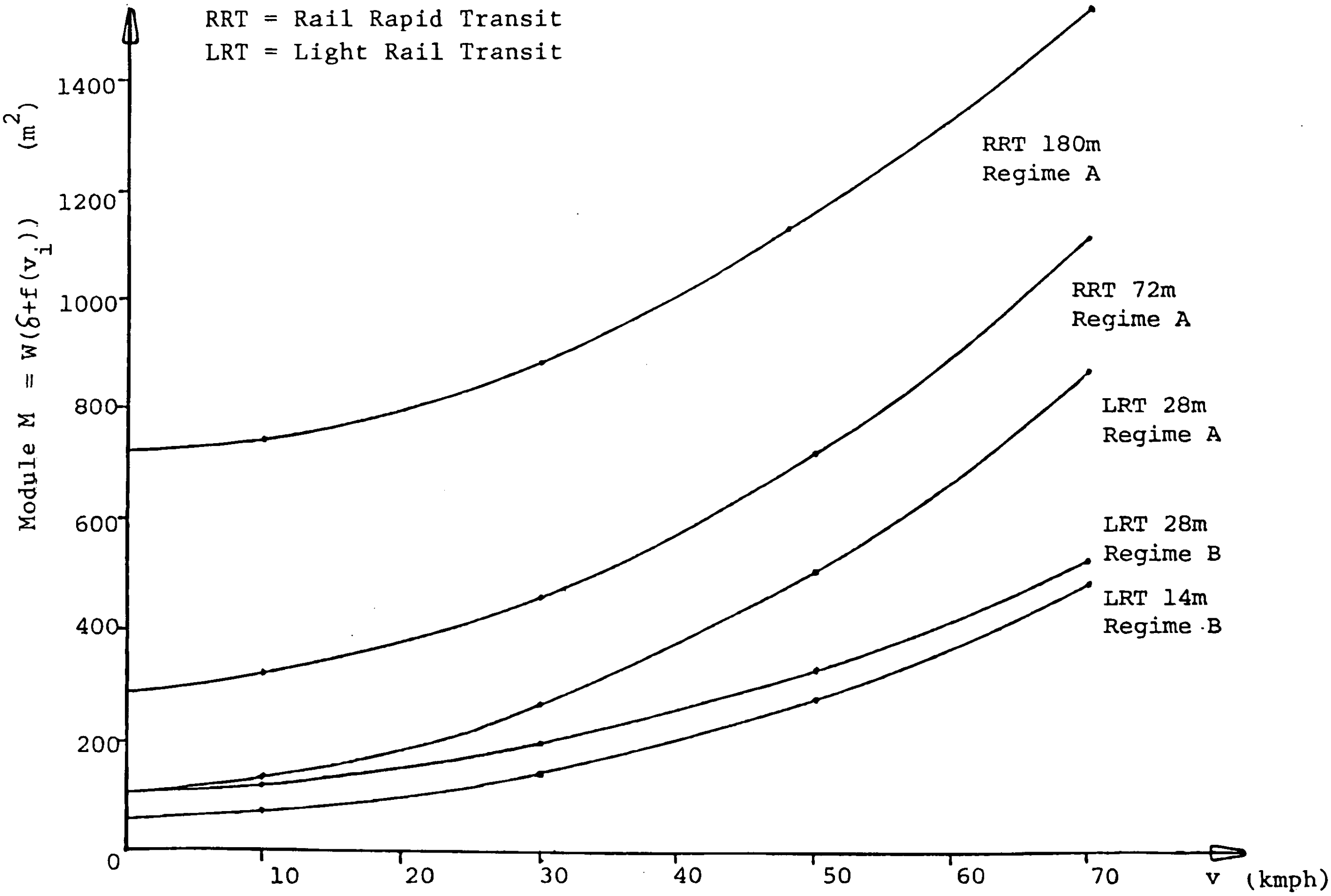


FIGURE 2 Time-area modules of rail transit vehicles.

Equation 9 gives the time-area consumption per vehicle in the course of occupying and traversing the analysis area of size *WS*.

For many purposes, it is not necessary to be specific about the length of analysis area. In such cases, one can look at the consumption per unit length of right-of-way by dividing both sides of Equation 9 by *S*:

$$\frac{\overline{TA_i}}{S} = W\,\frac{L_i(v_i)}{v} = \frac{M}{v} \qquad \left(\frac{\text{m}^2\text{-s/m}}{\text{vehicle}}\right) \tag{10}$$

So far the formulas for time-area have all centered on consumption simply on a per-vehicle basis. Another very useful comparison is on a per-unit-of-transportation-work-performed basis, that is, the time-area consumed per passenger-kilometers performed. This is found by dividing the previous equation by the average number of passengers, or average occupancy, in the type of vehicle in question:

$$\frac{\overline{TA_i}}{(\alpha C_i)S} = \frac{W}{(\alpha C_i)}\,\frac{L_i(v_i)}{v} \qquad \left(\frac{\text{m}^2\text{-s}}{\text{pass-m}}\right) \tag{11}$$

where C_i is the capacity of vehicle type i and α is the average load factor for this type of vehicle while operating within the analysis area.

The simplified formulations given are not valid at zero speed. Instead, the time-area consumed while standing for time t on the right-of-way is given by the simple relation:

$$TA_i = W\delta t \qquad \left(\frac{\text{m}^2\text{-s}}{\text{vehicle}}\right) \tag{12}$$

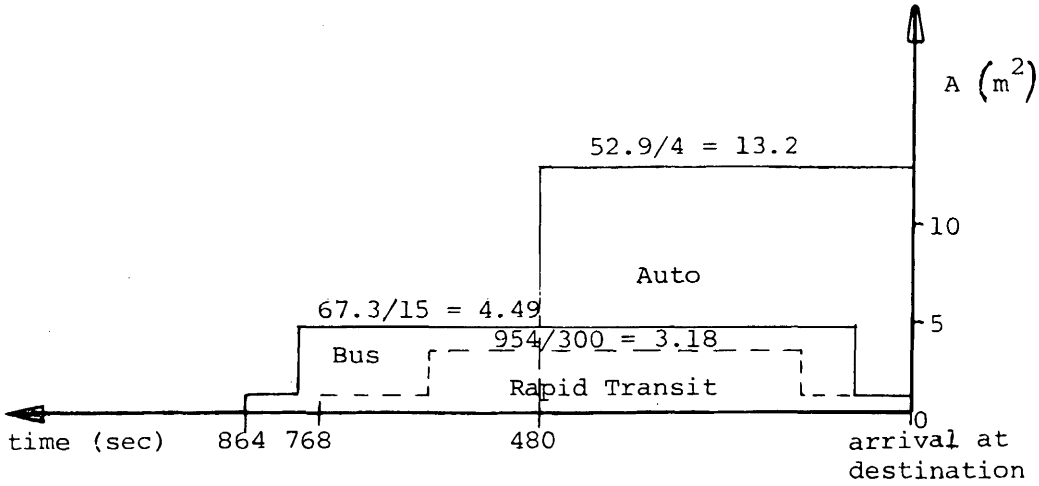
When a parking spot is used, the total parking lot size divided by the number of spaces is used to account for the maneuvering space inherent in the design of off-street parking lots. The area per vehicle is the total floor area divided by the number of spaces, or A_{eff}, the effective area per vehicle, so that

$$TA_i = A_{\text{eff}}t \qquad \left(\frac{\text{m}^2\text{-s}}{\text{vehicle}}\right) \tag{13}$$

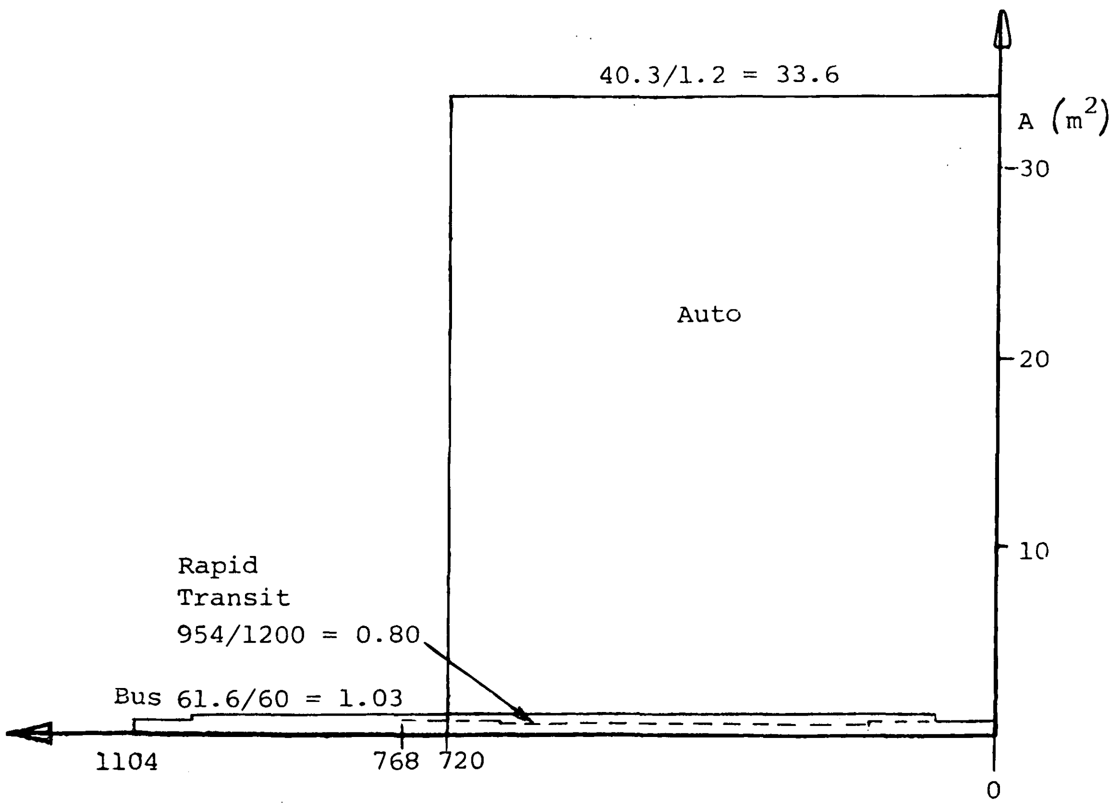
In a related vein, the general issue of how much area to attribute to the right-of-way for a mode can be problematic. Sometimes, only the lane width may be appropriate; in others, the minimal right-of-way width (e.g., road plus shoulders) or, in yet other cases, the entire right-of-way width should be used (e.g., the large amount of time-area consumed by rail stations, freeway interchanges, embankments, etc.). Therefore, careful consideration must be given when computing static time-areas, perhaps by using an effective right-of-way width.

AN EXAMPLE IN URBAN LAND-USE ANALYSIS

A numerical example for evaluating consumption along a path using equations introduced in the previous section, with a few added details, is plotted in Figure 3 for a hypothetical commuting trip per-



a: Off-peak period travel



b: Peak period travel

FIGURE 3 Time-area consumed per passenger on a 4-km-long trip using three different mode choices.

formed by three different mode combinations: (a) walking 100 m to a bus stop, followed by a 4-km bus ride, and again walking 100 m to the destination; (b) walking 200 m to a rapid-transit station, followed by a 4-km train ride on an at-grade right-of-way, again followed by walking 200 m; and (c) driving virtually door to door in a 5-m-long private automobile. The road right-of-way width is 3.7 m, the rapid-transit right-of-way width is 4 m, and an off-street parking module A_{eff} of 25 m^2 is assumed. The pedestrian module and speeds for a commuter are based on values developed by Fruin (*12*). The additional values assumed and some calculated results are summarized in Table 2.

In this example, the calculation is performed and the results plotted for two different conditions; Figure 3a uses average occupancies and speeds appropriate for off-peak-period travel, while Figure

TABLE 2 Summary of Values Used in Example Time-Area Calculation for a 4-km Trip and 8-hr Stay Using Three Different Modes

Assumed Values

MODE / VARIABLE	Automobile Peak / Off-peak	Bus Peak / Off-peak	Rapid Transit	Pedestrian
following rule	16 kmph increment	16 kmph increment	safe, regime A	N/A
speed [kmph]	20 / 30	15 / 20	30 (operating)	5
occupancy [prs/vehicle]	1.2 / 4.0	60 / 15	1200 (10 x 18m cars)	1

Calculated Values

MODE / VARIABLE	Automobile Peak / Off-peak	Bus Peak / Off-peak	Rapid Transit	Pedestrian
travel time = d/v [s]	720 / 480	960 / 720	480	72 to Bus 144 to RT
Module per vehicle [m^2]	40.3 / 52.9	61.6 / 67.3	954	0.83
Module per person [m^2]	33.6 / 13.2	1.03 / 4.49	0.80	0.83

3b uses values appropriate for peak-period travel. The assumed occupancies can be read off the figures as the denominators to the shown module per vehicle values. Recall from the previous section that average occupancies are used to convert time-areas from a per-vehicle basis to a per-passenger basis.

The ordinate on the diagram is the instantaneous area or module, while the abscissa is the elapsed time. The horizontal reference point is the arrival time at the destination, marked as zero, so that the values are actually plotted from right to left. Every time there is a transfer between modes, there is a change in the module required, and hence a vertical jump in the plot. The resultant areas under the curve are the time-areas consumed on each link. If a constant speed is assumed, as in the current example, the resulting shape under the curve for each link is a rectangle. (For increased accuracy, the rapid-transit alternative is not assumed to have a constant speed, instead operating speed is used.)

Figure 3 indicates that in this case auto travel has the advantage of a shorter horizontal dimension, time, but it also has a disadvantage of much greater vertical dimension, area. The difference is already pronounced in off-peak travel (Figure 3a), but is more dramatic during the peak period (Figure 3b). This is the result of decreased occupancies in automobiles and increased occupancies in transit vehicles during peak periods. Thus, individual automobile users tend to put the highest claim on limited road resources (road area) at the very time that the maximum vehicles are on the road. Note also that during the peak under the assumed conditions (close to crush conditions), the rapid-transit train's time-area consumption per passenger is actually lower than for a pedestrian!

This type of diagram can be very revealing about the consumption of an urban district's available space resources assuming various splits between travel modes. If there is a contemplated change in modal split, the difference in total time-area consumption will be a good indicator of the impact. This difference is found by multiplying the consumption per person for each mode by the total number of persons affected, and then comparing it with the changes for each of the other modes.

Figure 4 extends the plot to include not only the links involved with the peak-period trip to work but also the 8 hours at work, followed by the trip home. Note that the module for parking is somewhat lower than the module for driving at low urban speeds, but parking is the dominant time-area consumption component because of its long duration. By comparison, the alternative modes do not require parking as it is generally possible to store public transportation vehicles at remote locations between the peak periods. (Even if a large aboveground terminal is used, as long as many passengers use it, the time-area consumed per passenger is still very low.)

This type of diagram gives additional information about the consumption of off-street space resources not shown on the previous figure. Again, differences in total time-area consumption among modes can be easily observed, and the impacts of a change in mode split can readily be computed. In this example, the much larger size of the time-area rectangle for parking than of the two rectangles for driving shows that the time-area dedicated during the day to parking facilities is greater than that required for driving on streets.

In addition to the module-versus-time format used in this example, another useful graphical display format is cumulative time-area versus time. In the previous figures the time-area was represented as the area under curves. Now the time-area is integrated and represented simply by the ordinate. Such a format indicates both the rate of consumption and the total time-area consumed by each type of user as the day proceeds. Figure 5 shows the same situation as portrayed in the previous figure but in the cumulative format. Not only does this type of diagram conveniently illustrate the total consumption up to any given time but the slope of the curve shows the rate of consumption; a horizontal line represents no consumption.

Again, one can see that the bus rider uses a very small fraction of the time-area of the automobile rider, and that the automobile rider continues to consume during the entire day as a result of parking requirements. Note that the module for off-street parking is 25 m^2 versus a modestly higher value of 40.3 m^2 while driving at 20 km/hr, which explains why the parking consumption component is so dominant; the long duration of parking is far more important than the difference in module size.

Finally, Figure 6 is another example of a cumulative consumption plot. It illustrates the effect of increasing auto occupancy from the peak-period average of 1.2 to 2.0, and then to 4.0 persons per auto. Note that while increases in auto occupancy reduce consumption considerably, the rate for a full car is still far higher than the consumption for even a quarter-full bus; the need to have parking nearby is an inevitable major cause of time-area consumption by automobile users.

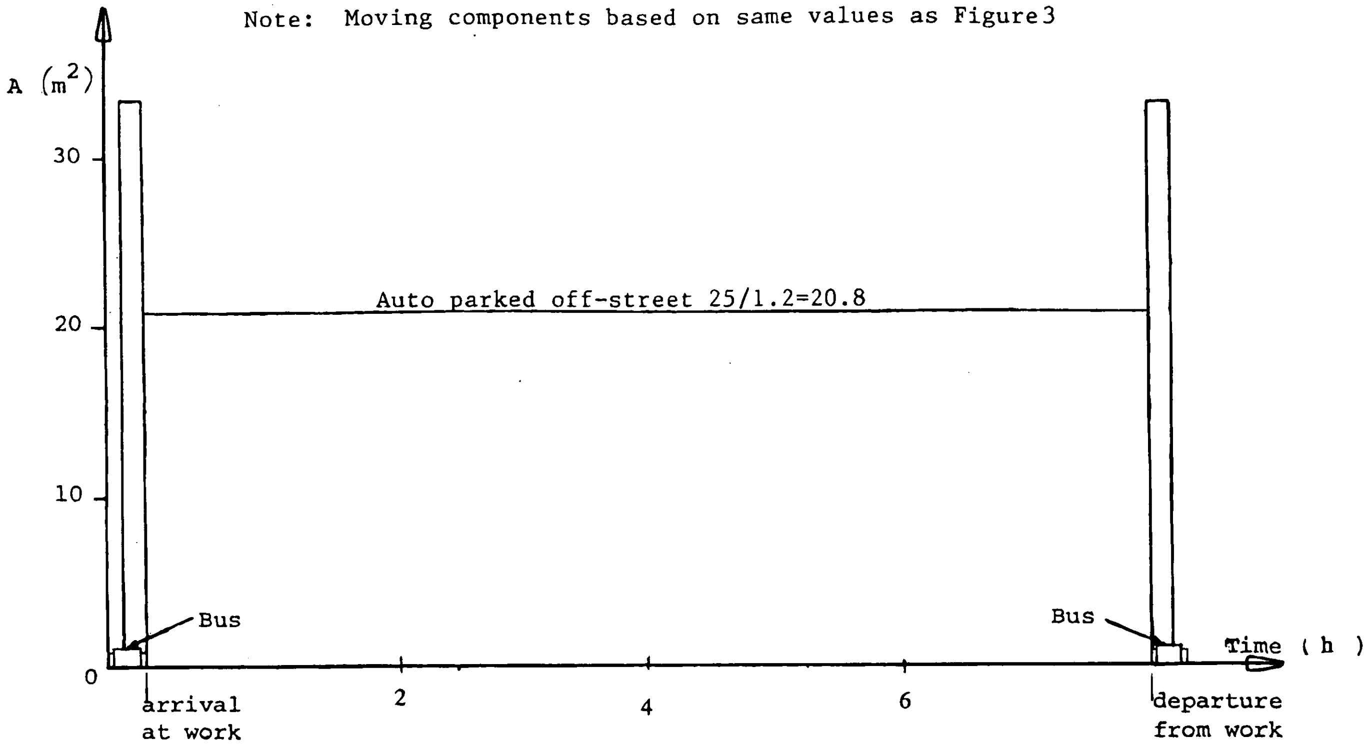


FIGURE 4 Time-area consumed per passenger on an 8-km round-trip commute using two different mode choices.

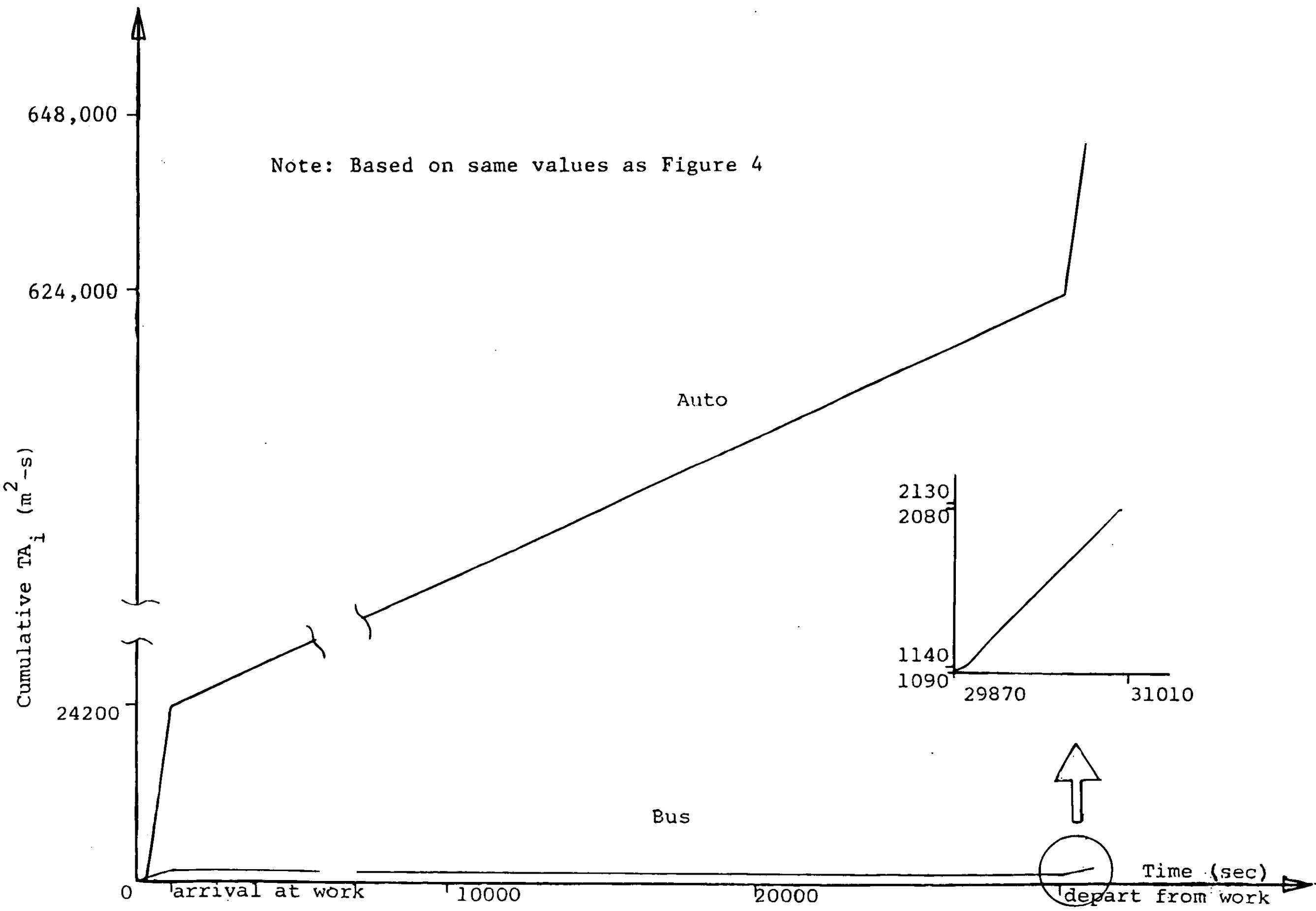


FIGURE 5 Cumulative time-area consumed per passenger on an 8-km round-trip using two different mode choices.

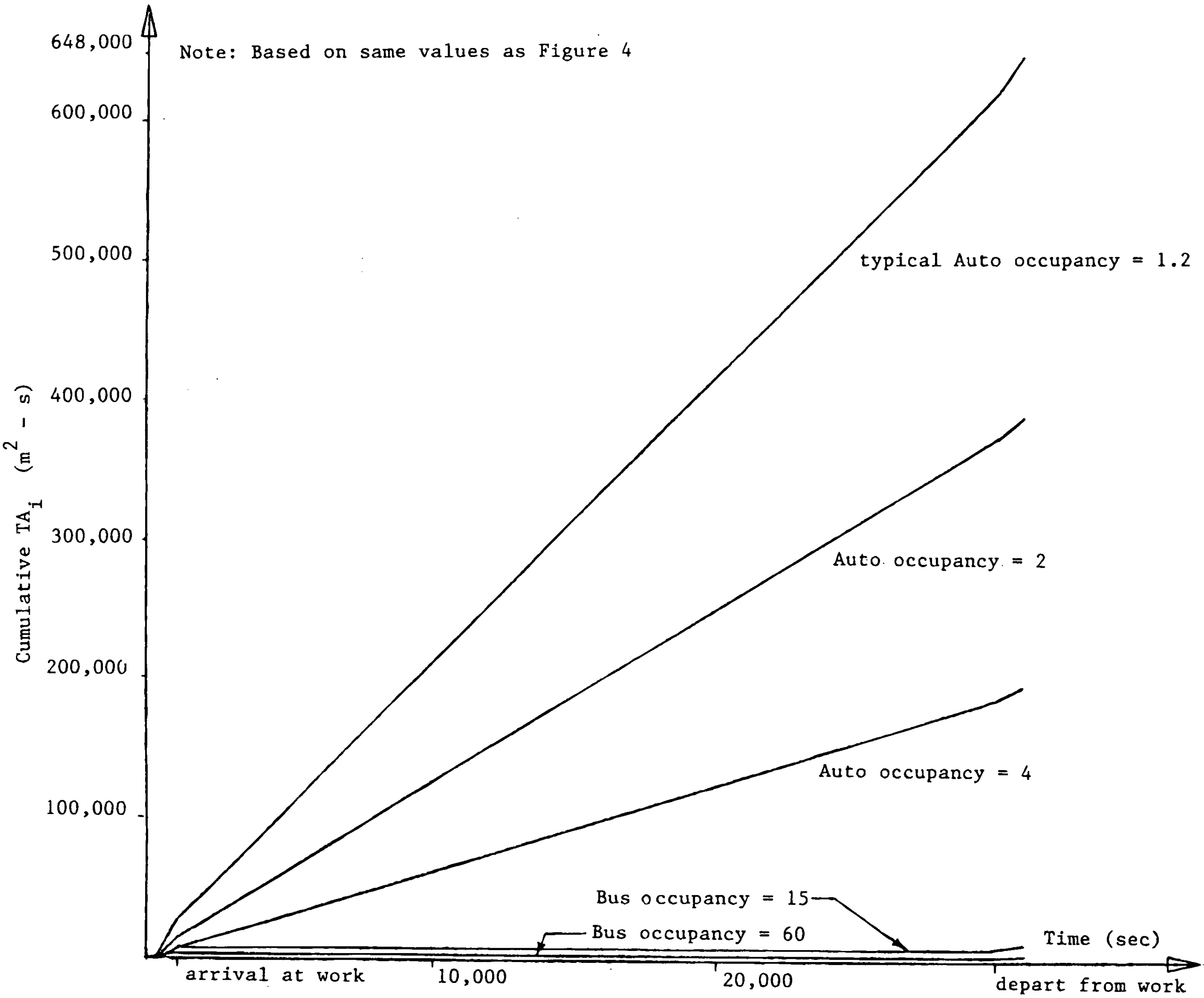


FIGURE 6 Cumulative time-area consumed on an 8-km round-trip comparing the automobile with a fully loaded bus.

SUMMARY AND CONCLUSIONS

The time-area concept—the product of the land area occupied by a vehicle and the time for which it is occupied—is a powerful one that had not been fully developed. Its history of development and limited applications were reviewed. It was found that practical applications have been confined to the design and operation of pedestrian facilities. The research presented here discusses other applications that have not been seen in practice. One of the authors developed this concept more fully as a doctoral dissertation; some of the resulting formulas for the important special case of moderate to heavy traffic moving at a constant speed have been presented here.

There are several types of analyses in which the time-area concept offers unique advantages, including:

- A joint analysis of land consumption by moving and standing pedestrians or vehicles;
- Relationships of consumed to available time-area, again for moving and standing vehicles;
- Comparison of total area consumption (static and dynamic) by different modes;
- Efficiency of land usage by different modes, assuming constant volumes of travel;
- Impacts of changes in modal split on land consumption; and
- Impacts from changes in vehicle occupancies.

An example case of a hypothetical commuter using three different mode combinations—including walking to and from a bus, walking to and from rapid transit, and traveling by private automobile—was analyzed and portrayed using time-area versus time diagrams and then cumulative time-area versus time diagrams. Some of the important characteristics of travel by the different modes that can be observed include the following:

- Auto offers time savings and convenience of not having to transfer, but these advantages are traded off against the much higher land area requirements needed for driving it.

- Parking all-day is the predominant component of time-area consumption of an auto commuter if travel speeds are slow because the somewhat smaller area requirement while parked than while driving is far offset by the long duration of parking.
- A passenger in even a fully loaded automobile consumes far more area than a person in a fully loaded bus, both while driving and while parked.

These findings are particularly important for transportation planning in urban areas with limited space.

In conclusion, the time-area unit can provide new ways to look at old problems in a number of analyses related to urban planning, and transportation systems analysis and design, like the example presented. It can also be used in specific applications such as design of multimodal transportation systems at major activity centers, determination of various land-use development taxes, or various schemes of road and congestion pricing.

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