MODELS FOR ASSESSING THE IMPACTS AND THE POTENTIAL BENEFITS OF INTELLIGENT TRANSPORTATION SYSTEM

A WORKING PAPER

Prepared for

IVHS Research Division

Joint Program Service

By

Ajay K. Ruthi

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Abstract

The absence of systematic analysis of the societal benefits and costs of Intelligent Transportation Systems (ITS) technologies -- in the short-term as well as long term -- is well recognized in the ITS community. This unmet need has been recognized, for example, by the Benefits and Evaluations Committee of ITS America. As public policy makers look beyond the current International Surface Traffic Efficiency Act (ISTEA) authorization, the question of "expected potential benefits" from ITS technologies are sure to be raised by the congressional committees. Yet, the available information is quite dated and may not be adequate for presenting a compelling case. This working paper is an attempt to put the issue of "models to evaluate potential ITS benefits" in a programmatic perspective, so that groundwork is laid for future Federal Highway Administration (FHWA) efforts on the subject matter or modeling related projects. Following a description of a meeting that took place at the FHWA on June 21, 1995, this working paper begins with a problem definition and discussion of modeling requirements as it relates to evaluating alternative ITS technologies and user services. Based on these requirements, conceptual and analytical frameworks for assessing the benefits of ITS technologies are discussed. The paper then provides a summary of current capabilities vis-a-vis identified requirements. The options for future FHWA efforts are presented and some recommendations made. Some brief proposal ideas are included as Appendix A.

1. Background

On June 21,1995, a meeting was held at the Federal Highway Administration (FHWA) to discuss modeling capabilities for evaluating ITS strategies. This meeting was attended by Mel Cheslow (JPO), Al Santiago (TFHRC. HSR-11), Fred Ducca (HEP-22), Brian Gardner (HEP-22), and Ajay Rathi (Oak Ridge National Laboratory, ORNL) The primary motivation for this meeting was to discus an unmet need in the ITS R&D efforts: absence of analytical tools (i.e., models or a modeling system) to assess the impacts and potential benefits of alternative ITS strategies, taking into account all relevant effects of ITS technologies on the transportation system's demand, supply, energy consumption, air quality, and traveler behavior.

Several on-going modeling efforts were discussed in the meeting, with a focus on what is being done, what will be available, and when. Following this meeting, FHWA tasked ORNL to put together a working paper that could be used by the Federal Highway Administration in its program planning, specifically with regard to directions for the future modeling efforts.

This paper summarizes the findings of this assignment. These findings are based on my understanding of the problem as well as the current capabilities. a review of literature that I obtained from FHWA after the meeting, and other relevant literature. internal discussions within ORNL's Center for Transportation Analysis staff. and discussions with some notable experts in the profession.

Since the June 21 meeting. the work to date has tried to:

(1) develop a clear definition of the problem and the associated functional requirements;

(2) a quick review of on-going work:

(3) discussions with experts on the subject area and solicitation of recommendations (as short proposal ideas); and

(4) recommendations for the most useful directions to pursue.

The following sections summarize the findings of the effort to date in each of these four activities. Please note that this paper presents work in progress. The format has been developed to allow easy updates as further discussion takes place.

2. Problem Definition

Much of the work on Intelligent Transportation Systems to date has emphasized technologies. standards/protocols. user services. architecture. costs. and various other technical and institutional issues. Suprisingly, the issue of rigorously and faithfully evaluating "alternative

ITS strategies” and estimating their benefits have been given only secondary (if any) considerations. Questions such as “what are the expected traffic operational benefits from a given ATMS and ATIS strategy for a region during the peak hours” have not been yet answered. In addition, the research and development to date has not established and verified methods of evaluating the energy, environmental. and safety impacts of ITS.

The absence of any systematic analysis of benefits and costs which includes all relevant effects (primary and secondary) of ITS technologies on the transportation system -- in short-term as well as long term -- is well recognized in the ITS community. This, for example. has been recognized as a priority area of research and development needs (unmet to date) by the ATMS and Benefits and Evaluations (B&C) Committees of ITS America. As public policy makers look beyond the current ISTEA authorization, the question of expected benefits from ITS technologies are sure to be inquired by the congressional committees and others. In this regard, the avaiiable information (used in initial justification for ITS programs) is quite dated and may not be adequate for making a compelling case before the Congress.

At the same time, the Federal Highway Administration has several on-going modeling and related efforts. With the exception of a FHWA/USDOT project managed by Volpe National Transportation Center (VNTSC). none of these efforts are attempting to address this problem directly and in its entirety. While the work performed by VNTSC does provide an acceptable framework for assessing the impacts and potential benefits of ITS user services. the models used in Voipe’s ITS Benefits Framework study seem to have limited its application to the evaluation of short-term ATMS benefits. Further. the attempt to simulate ATMS strategies in urban networks using the FREQ and TRANSYT-7F models raises serious questions about the utility of the overall effort. Most other models and projects have not attempted to (nor are planning to) analyze the long-term effects of ITS on the transportation system. Many of these er’forts are aimed at solving a subproblem or a subclass of the overall problem. For example. the TRANSIMS effort (when completed‘) may not support ITS features such as dynamic traffic assignment or RT-TRACS which can be considered as the heart of ATIS and ATMS concepts, respectively.

In response to the impending need for evaluating ITS alternatives prior to deployment of these systems. the Joint Program Office (JPO) of the ITS has identified the following program need:

Model(s) [or Analytical Tools] are needed for systematically and faithfully evaluating alternate ITS strategies. These models couid be used by the JPO itself (or its support contractors) for ITS national policy analysis. These models could also be used bv the Metropolitan Planning Organizations (MPOs) to evaluate alternate ITS srraregies as part qf‘the pianned ITS deployments in their regions. Current (on-going) modeling efforts, though many, are not addressing these two separate needs within the desired time schedule. and are not addressing many key issues such as the dynamic aspect of traffic operations under ATIS*

During the discussions the “domain” or "scope or the problem” was identitied as follows:

For now, ITS areas of interest are ATMS and ATIS. That is, the scope of evaluation capabilities will be limited to ATMS/ATIS applications. However, the modeling framework (architecture) should be such that it would support CVO, AVCS, and other applications in the future with relatively easy update.

The spatial extent of ITS evaluations was identified as a "region."

The time schedule for model development and availability was identified as near-term availability and mid-term availability. The near-term availability for a model to be used by FHWA (JPO) or its support contractors was targeted at early '96, and mid-term availability by the end of CY 96. However. because of the greater robustness and friendly user-interface needs of a model for MPOs. near-term availability is desired at the end of CY 96 and mid-term in mid- or late CY 98.

However, the following elements of the problem were not clearly defined:

Within ATIS/ATMS, specific technologies or user services or deployment scenarios were not defined. [The VNTSC work did define deployable ITS technologies and strategies. Table 1 shows the various ATMS. ATIS. and APTS strategies that could be deployed. This may be a good starting point. However, MITRE and JPL architecture support teams might want to update the list.]

The "temporal extent" of evaluation was not established. That is. evaluation can be done for a 15-minute period to a time horizon of 15-years. Depending upon the temporal extent of an evaluation. different types of models may be needed and different elements of traveler behavior and transportation demand patterns may have to modeled. [I have assumed a 1-5 year analysis period. That means. the changes in land use patterns that result from ITS technologies need not be modeled.]

3. Functional Requirements

The purpose of the models [or analytical tools] is to provide a capability for evaluating the benefits of deploying ITS technologies in a region. The time frame of analysis would be l-5 years.

Within the desired time schedule. the models shouid represent as much as feasible of the following:

- an Inter-modal regional transportation network including highway network detail down-to minor arterials and mass transit routes:

- changes in: trip generation, mode split, O-D matrix (including those resulting from trip chaining), trip departure time, route selection, and route following as a result of ITS strategies (i.e., unique travel decisions);

- key operational features of the highway network in a region including various types of signals, ramp metering, changeable message signs, high-occupancy lanes, etc. This requirement applies to both the simulation and planning models which are likely to comprise the framework;

- dynamic aspect of traffic including spillback, incidents, merging and weaving, etc.; and

- transportation system entities (characteristics) in sufficient detail to allow assessment of energy, environmental, and safety impacts by additional analytical modules.

In addition, the model(s) should:

- be based on sound theories of transportation demand and supply characteristics, traffic flows, and traveler behavior. etc.:

- provide traffic operational measures of effectiveness (congestion, travel time, speed, delays, etc.) as well as energy, environmental, and safety measures of performances for the base year as well as 2 to 5 years in the future;

- realistically simulate transportation network performance under ITS strategies, specifically the user services and technologies under ATMS/ATIS likely to be deployed in next ten-years:

- have friendly user-interfaces (preferably a GIS for the versions made available to MPOs);

- be computationally efficient and preferably operate in a PC environment for the versions made available to MPOs: and

  limit the data requirements both for the baseline and ITS alternatives from the users to the extent practical.

Some programmatic requirements for the effort are as follows:

- models must be developed. verified. and beta tested in the desired time schedules for both the JPO and MPO versions. For example. The time schedule for model development and availability has been identified as near-term availability and mid-term availability. The near-term availability for a model to be used by FHWA (JPO) or its support contractors was targeted at early ‘96. and mid-term availability by the end of CY 96. However, because of the greater robustness and friendly user-interface needs of a model for MPOs, near-term availability is desired at the end of CY 96 and mid-term in mid- or late CY 98.

- to develop the capability, existing models should be used as much as possible. Where possible, the use of commercial software (proprietary) should be avoided.

- near-term version of the model or modeling systems developed for the MPOs must be field tested using data from at least three different metropolitan regions by September 1997.

Please note that these are generic functional requirements. Associated with each of these requirements are several specific (technical) requirements that can and should be derived as part of the project effort that might be undertaken.

4. Conceptual and Model Frameworks

This section discusses the conceptual and model system architectures or frameworks that can provide the approach and tools necessary to evaluate how the implementation of ITS technologies may impact congestion, travel time. air quality, fuel consumption. and safety. The conceptual framework defines the steps necessary to accomplish the objectives whereas the model framework identifies the specific models/procedures and their linkages.

Figures 1-3 show three alternative conceptruai frameworks for assessing the impacts and potential benefits of ITS technologies. Figures 4 and 5 show the model frameworks for VNTSC and TRANSIMS projects.

The similarities in the conceptual framework adapted by three different projects is no surprise. It is simply restating that changes in unique traveler decisions as a function of ITS technologies must be accounted for and modeled appropriately. The VNTSC and TRANSIMS model framework add air quality. energy, and safety impacts as the outcome of the assessment in addition to traffic operational measures such as congestion, mobility, etc. There are some fundamental differences in the TRANSIMS's and VNTSC's approach. TRANSIMS is based on microsimulating travel activity patterns whereas VNTSC approach is based on traditional 4-step process (i.e.. individual trips). Further. VNTSC's framework did not consider changes in trip generation as a result of ITS technologies.

The VNTSC framework is based on linking several models. As of May 1995, the framework includes: a regional planning model. a simulation model. an arterial optimization/simulation model. two models to estimate the fuel consumption and emission impacts. and a model to assess safety impacts of alternative ITS strategies. With the exception of the safety model. the VNTSC effort has utilized existing models. The TRANSIMS approach is to develop an integrated model while building its components almost from scratch.

Since the early days of discussion on benefits of ITS technologies and for many years before that, the transportation profession has recognized that, on a regional basis, neither the operational models nor the planning models by themselves are capable of assessing the full societal and economic impacts of alternative transportation system management strategies. For example, the assessment of the travel demand management strategies in 1970s strongly suggested the need to merge or link the planning and operational simulation models. The new requirements from the 1990 Clean Air Act Amendment (CAAA) and ISTEA legislation broadened the analysis envelope further to include the energy, environmental, and safety modeling as an integral element of the impact assessments procedures. The emergence of ITS technologies and concepts have added a new dimension to the problem—modeling and assessment of impacts of dynamic traveler behavior in response to information.

Unfortunately, the VNTSC framework has left the modeling of traveler behavior and many ITS services as "issues not addressed" and had identified those as future efforts. Similarly, it is not yet clear as to what aspects of dynamic traveler behavior and representation of ITS technologies and user-services (e.g., in-vehicle navigation system, RT-TRACS) will be incorporated in the TRANSIMS travel microsimulation component. Note that this is not a criticism of these efforts. They may be right on target given the time and budget constraints, FHWA directions, and other external and internal factors that influenced these project efforts. For example, the VNTSC effort used improvement in and linkage of existing "in-house" models in order to be responsive to the project objectives with the available 4-month time period to produce an operable system.

The frameworks developed in both of these efforts is certainly a step in the right direction and—with some additional capabilities—may be responsive to meet the objective of assessing at least some of the benefits resulting from ITS technologies and user services. Regardless, an acceptable framework must be capable of faithfully representing the ITS technologies (e.g., simulating transportation system under ITS services) as well as estimating and predicting the changes in unique travel decisions of the travelers.

5. Current Modeling Efforts

In March 1995, The MITRE corporation prepared a report for the Joint Program Office entitled "A Survey of Federal Highway Administration Sponsored Traffic Modeling Projects." In addition to documenting the modeling and simulation projects currently sponsored by the FHWA, the report identified the gaps or overlaps among the on-going efforts. The analysis of gaps and overlaps is approached through a comparison of projects and models against each other and against identified modeling capabilities required by the sponsors or evolving transportation paradigm. The effort also involved a survey of traffic planners and operations manager to learn of their modeling needs.

The report contains a good synthesis of on-going modeling efforts and related projects. The review, however, lacks in-depth discussion of many key technical issues (e.g. capabilities of the models, modeling technique, etc) as well as independent assessment of the efforts and model capabilities. A survey of experts in the field regarding various models might have been added more value to the report. In the area of gaps, the report does identify some of the desired modeling capabilities that seem necessary but are not being addressed or will not be available in the near future. Interestingly, the need for a model or a system to evaluate ATMS/ATIS strategies is not explicitly identified as a gap. The report states that THOREAU and INTEGRATION may be "well-suited for studying the potential benefits of ITS." In the area of overlaps and model development schedule, several issues have been correctly identified. The report does emphasize the need for better communication between various offices of the FHWA.

For the particular issue of interest to this paper, the report is a good starting point. However, since the writing of this report, some new developments have taken place:

1. The near-term plans for the TRANSIMS model has been firmed up. The "Travel Microsimulation" component has been identified as the first Interim Operational Capability (IOC). The goal is to test the capability this summer. The second IOC is the air analysis capability integrated with the travel microsimulation.

2. The National Institute of Statistical Sciences (NISS) has started a new project entitled "Measurement, Modeling, and Prediction of Infrastructural Systems" under the sponsorship of the National of the National Science Foundation (NSF). Alan Karr, Associate Director of NISS is Project Director. Eric Pas (Duke University) is a co-principal investigator. Two research thrusts of the project with implications on FHWA modeling efforts are: travel demand forecasting for urban transportation; and network modeling for ITS, with emphasis on systems for real-time route guidance and planning. The study is funded for a five-year, $6M level of effort. For reasons not known, the effort seems not to emphasize the ATMS aspect of network modeling. The researchers involved with network modeling of ATIS have contacted the Turner-Fairbank Highway Research Center (TFHRC) and expressed interest in coordinating/cooperating with the modeling efforts of the FHWA. See attached announcement for more information on the project.

3. ORNL, on behalf of FHWA, has recommended The Massachusetts Institute of Technologies (MIT) and The University of Texas Austin (UT Austin) as the contractors for Phase I of the Real-Time, Dynamic Traffic Assignment (DTA) System project. This effort is being managed by ORNL for the FHWA. The DTA system is defined as a system that is to serve as an integrator between the ATMS and ATIS and to provide the following capabilities:

    - Estimate and predict traffic network states; and
    - Provide descriptive and prescriptive route guidance information to the traveler based on such estimates.

    It should be noted that the estimation and prediction of traffic network states is a capability that is needed for both on-line applications as well as off-line planning applications such as those required by the JPO and the MPOs. These capabilities are not supported by the existing planning and simulation models which do not take into account the dynamic nature of unique travel decisions. As such, the capabilities derived from the DTA system are essential for the framework to assess the benefits of ITS alternatives.

The MIT and UT Austin have done pioneering work in the area of dynamic traffic assignment model. In the last two years, both MIT and UT Austin have continued their work with funding from the FHWA and other sponsors Dr. Hani Mahmassani and his group at UT Austin has made several changes in the DYNASMART model including porting it to workstations from the CRAY-supercomputer platform, several enhancements to the simulation logic, rolling horizon implementation for ATIS, k-shortest path algorithm, etc. By using DYNASMART as a tool to evaluate network performance under ITS, a day-to-day analysis framework has been developed to study day-to-day evolution of network flows under real-time information The MIT group has also worked extensively on the MITTNS and DYNA models as part of other efforts (e.g. Boston Central Artery Project). The MITTNS (MIT Traffic Network Simulator) is a simulation-based predictive DTA model with the foilowing components: a real-time Origin-Destination Estimation and Prediction Module. a Driver Behavior Module. a Traffic Routing Module and a Traffic Control Module Interface. Both these efforts will produce a prototype DTA system by the end of CY96.

Based on my recent conversations with Profs. Ben-Akiva and Mahmassani. it appears to me that both these groups are quite capable of extending their current models to provide a much better analytical framework for estimating ITS benefits as desired by the JPO. Both of these experts also stressed the need for better estimation of network performance under ATIS and ATMS and better data on traveler behavior modeling. This paper has been reviewed by Profs. Ben-Akiva and Mahmassani who have also provided (per my request) a brief proposal idea on their approach to address the issue at hand.

In addition. there are several other non-FHWA sponsored efforts (not included in the MITRE report) which might be useful for the assessment of the benefits of ITS alternatives:

1. With funding from the Colorado DOT and FHWA. Dr. Bruce Janson has continued his work on the DYMOD (for DYnamic traffic MODEL) model which provides a means of predicting time-varying traffic conditions in fairly large yet quite detailed urban transportation network DYMOD is formulated as a mathematical programming problem and as such it is an Integrated model unlike the simulation-assignment based dynamic traffic flow models. The DYMOD work was began at ORNL as an internal R&D project under the direction of Dr. Frank Southworth. The model can meet many of the functional requirements listed in Section 3 and as such is a viable candidate. The model is being applied in the Chicago and Denver area . A proposal idea from Drs. Souhtwo and Janson is included in Appendix A along with a copy of Dr. Janson's recent letter to the FHWA regarding DYMOD and its applications.

2. With funding from Indiana DOT and FHWA, Prof. Kumares Sinha and his colleagues at the Purdue University are also attempting to develop a framework for assessing ITS benefits. The ITS technologies being deployed in Northern Indiana area (Borman Project and Indiana Toll Road) have generated the need for analytical tools to evaluate the impact of alternative ITS technologies. The Borman Expressway ATMS project is part of USDOT's Gary-Chicago-Milwaukee ITS priority Corridor. Another focus area of the Purdue researchers is the calibration, validation, and verification of these models and a information management system for monitoring and tracking the transportation system's performance in future years to validate the modeling frameworks and assumptions.

Purdue's is a multidisciplinary effort with expertise in traffic safety and control, travel demand modeling, network analysis including dynamic traffic assignment, air quality modeling, economics, and statistics. Basic components of the framework are based on extensive research done in recent years with funding from TRB, FHWA, and INDOT. These include O-D matrix estimation, behavioral models for route choice with ATIS. dynamic incident response decision making, real-time traffic assignment, incident prediction based dynamic traffic assignment, and regional air quality modeling.

The VNTSC project (discussed earlier) is perhaps the most reievant and direct attempt by the FHWA to address the issue of assessing the impacts and potential benefits of ITS technologies. The project's objective was to "provide analytical tools necessary to assess the potential benefits of IVHS strategy" . . precisely the objective that the JPO would like to meet. Obviously, the VNTSC effort has not met the objectives as originally envisioned. Also, there are several technical issues with the models that have been used in the analysis framework. Nonetheless, the effort has produced some good reports covering areas such as: definition of ITS strategies (see Table l), identification of key traveler behavior variables that would be influenced by ITS technologies and strategies (see Table 2). and interrelationship between these variables.

The VNTSC report also contains a table summarizing the deficiencies of existing models and an evaluation of several simulation models. A report from MITRE also contains an evaluation of several simulation and DTA models.

The results of my review of current modeling efforts vis-a-vis requirements for estimating ITS benefits are summarized in Table 3. The table provides a matrix of on-going modeling efforts and the desired capabilities based on the functional requirements identified in Section 3. In this table. however. the models and the efforts are compared on the basis of broad functional requirements rather than detailed technical requirements (as done by VNTSC or MITRE in their evaluation of the existing models). *Note that none of the existing models adequately meet the functional requirements identified in the context of evaliating ATIS/ATMS benefits.*

6. Options

Based on the work to date and the review of on-going modeling efforts, I have identified the following viable options (models or modeling systems) for assessing the impacts and potential benefits of ITS technologies and user services:

1. INTEGRATION + THOROUGH + PLANNING MODELS
2. Enhanced VNTSC IVHS Benefits Assessment Framework
3. DYMOD
4. DYNASMART
5. MITTNS
6. Enhanced TRAF Model Family
7. Purdue ITS Benefits Assessment Framework
8. TRANSIMS

The first and last two options (1, 2, 8, and 9 invoive enhancements or modifications to the modeling efforts that are currently funded by the FHWA. The other four options represent work that is being proposed. or extensions of non-FHWA funded work that is currently underway, or the FHWA funded work which is not yet started.

In terms of availability, the first two options are likely to provide the near-term operational capabilities for the JPO. Both of these efforts are also now managed and funded through the JPO. The next four options can be considered as viable options for mid-term operational capabilities for both the JPO and MPO usage. These four efforts are supported by TFHRC. The last two options can be considered long-term modeling capabilities with rather comprehensive frameworks and extensive modeling features. For example, the TRANSIMS effort can be modified to support almost all user services. The PURDUE effort can be applied to estimate expected national level benefits of various user services.

Fred Ducca has correctly pointed out while commenting on the first draft of this paper that:

The general issue is a tradeoff between time, cost, and (technical) accuracy. Any of the approaches (options) described. given enough time and money, could probably become the basis of'an assessment framework.

Given below is a summary discussion or' pros and the cons of each option along with a description of the required modifications and enhancements to assess the impacts of ITS technologies and user services.

INTEGRATION + THOREAU + PLANNING MODELS

Enhancements Required:

Develop Capabilities of Planning Models. i .e. Estimation and Prediction of Trip Generation, Mode Split, Trip Distribution. and Trip Departure Time and How These Variables are Impacted by ITS Technologies and User Services
Linkage of the Component Models
Friendly User Interface
Extension of THOREAU to support Large Regional Networks
Modeling Support for Additional ATMS/ATIS Strategies
Safety Impact Assessment Modeling
Improved Traffic Simulation and Dynamic Assignment Model
Support for Intermodal Transportation Networks

Note: New capabilities are being developed for INTEGRATION and THOREAU models as part of the ITS systems architecture effort. Hence. these assessment may not be up to date.

Pros:
Preferred and Used by FHWA
FHWA Funded. On-Going Effort
Usage in ITS Architecture Studies
Sufficiently Detailed
Availability on Workstations and PCs
Flexible Modeling Framework

Cons:
Major Enhancements Required
Credibility of Air Quality, Energy, and Traffic Models
Representation of Dynamic Travel Behavior
Proprietary Software
User Interface Will Need Significant Enhancement

Enhanced VNTSC

Enhancements Required:
Modeling to Assess the Impact of ITS on Trip Generation
Modeling Support for ATIS Strategies
Dynamic Traffic Flow Modeling
Support for Intermodal Transportation Networks

Pros: FHWA Funded, On-Going Effort
Established Framework
Some of the Model Linkage Code Could Be Reused
Availability on Standard Workstations and PCs
Test Data Available

Cons: Major Modeling Enhancements Required (Almost Equivalent to Starting From Scratch)

DYMOD

Enhancements Required:
Modeling rhe Impact of ITS Technologies on Trip Generation and Mode Split
Modeling Support for Additional ATMS/ATIS Strategies
Energy, Environment. and Safety Impact Assessment Modeling
Support for Intermodal Transportation Networks

Pros: Integrated Modeling
Consistenr Approach to System Evaluation
Theocratically Consistent and Sufficiently Detailed
Applications in Chicago and Denver Area
Complimentary to the FHWA DTA Effort
Availability on standard computing platforms (Workstations and PCs)
Reasonable Run Times
Models Changes in Trip Departure Time
Non-Proprietary

Cons: Purely Mathematical Model
Support for Many ATMS/ATIS Strategies May Not Be Possible
Major Enhancements and New Modeling Capabilities Required
Issues of Model Verification/Validation

MITTNS/MITSIM

Enhancements Required:
Link with Planning Models
Impact (Safety, Air Quality, Energy) Modeling (Modeling)
Support for Intermodal Transportation Networks

Pros: Most Individual Components of Assessment Framework
Piggy-Back with FHWA DTA Effort Possible
Usage in Boston Central Artery Project
Availability on Standard Workstations and PCs
Simulation Model is Sufficiently Detailed
Good User Interface
Object-Oriented Programming

Cons: ATMS Modeling Capabilities
Data Requirements
Verification/Validation/Acceptability of the Component Modules
Enhancements and New Modeling Capabilities Required

DYNASMART

Enhancements Required:
Support for Planning Model Capabilities
Safety Impact Assessment Modeling
Enhancements for Inter-modal Transportation Networks

Pros: Piggy-Back with FHWA DTA Effort Possible
Usage in Texas. California. Indiana, Ohio. and Taiwan
Availability on Standard Workstations and PCs
Simulation Model is Sufficiently Detailed
Flexibility to Represent Tripmaker Response Behavior Realistically
Incorporates Day-to-Day Dynamic Evaluation Framework
Advanced DTA Capabilities for Centralized and Decentralized ITS
Architectures Compatible with Activity-Based Microsimulation
Approach for Travel Demand Modeling

Cons: Limited ATMS Modeling Capabilities
Data Requirements
Verification/Validation/Acceptability of the Componenr Modules

PURDUE FRAMEWORK

Enhancements Required:

Develop Models for Estimation of Medium-Term and Long-Term Travel Impacts of ITS
Safety and Environmental Impact Assessment Modeling
Support for Intermodal Transportation Networks

Pros:

Modeling Framework Consistent with ITS Benefits Evaluation Requirements
User Behavior Model That Explicitly Accounts for Drivers' Confidence in and Perception of ITS Information
Sufficiently Detailed Simulation Model
Availability on Standard Workstations and PCs
Usage in Borman Expressway ATMS Project in Northern Indiana
Real-Time Test Data Available
Application Contemplated for the Indianapolis Early Deployment Program
Flexible Modeling Framework with an Organized Data Collection Program for Periodic Validation
Highly Suitable for MPO Applications

Cons:

Timely Availability of the JPO Version (Applications)
Verification/Validation of Model Components
ATMS Modeling Capabilities

Enhanced TRAF

Enhancements Required:

Develop Capabilities of Planning Models. i .e. estimation and prediction of trip generation, mode split. trip distribution. and trip departure time and how these variabies are impacted by ITS technologies and user services)
Modeling Support for ATIS Strategies
Dynamic Traffic Flow and Assignment Modeling
Safety Impact Assessment Modeling :
Support for Inter-modal Transportation Networks

Pros: Preferred and Used by FHWA
FHWA Funded. On-Going Effort
Availability on Standard Workstations and PCs
Simulation Models are Widely Used and Accepted as Standards in Profession
Superior User interface
Flexible Model Architecture
Non-Proprietary
Structured Programming

Cons: Timely Availability
Major Enhancements and New Modeling Capabilities Required

TRANSIMS

Enhancements Required:

Representation of ITS technologies and user services (e.g., RT-TRACS) within the travel microsimulation component
Dynamic Traffic Flow Modeling

* Assuming that all the functional capabilities as planned will indeed be supported by the model.

Pros: On-going FHWA effort
Complete modeling framework

Cons: Availability (in next 12-months)
ATMS/ATIS Modeling Capabilities
Data Requirements
Verification/Validation/Acceptability of the Component Modules
Uncertainty about the Computing Platform
Computational Efficiency
User Interface (Unknown)

7. Conclusions and Recommendations

Much of the work on Intelligent Transportation Systems to date has emphasized technologies, standards/protocols, user services, architecture, costs. and various other technical and institutional issues. Surprisingly, the estimation of the consequences of "alternative ITS strategies" are often shrouded in uncertainty. Simple questions such as "what are the expected traffic operational benefits from a given ATMS and ATIS strategy for a region during the peak hours" have not been yet answered. In addition, the research and development to date has not established and verified methods of evaluating the energy, environmental, and safety impacts of ITS.

The absence of any systematic analysis of benefits and costs which includes ail relevant effects (primary and secondary) of ITS technologies on the transportation system -- in the short-term as well as long term -- is well recognized in the ITS community. As public policy makers look beyond the current ISTEA authorization. the question of expected benefits from ITS technologies are sure to be inquired by the congressional committees and others. In this regard, the available information (used in initial justification for ITS programs) is quite dated and may not be adequate for making a compelling case before the Congress.

None of the existing models or analytical frameworks are fully capable of providing a systematic and faithful assessment of the impacts and benefits of ITS technologies for a region for an analysis period of up to 5-years. The existing models and data provide an inadequate foundation for satisfactory assessment of both short-term and long-term implications. In addition. the knowledge gaps in our understanding of travel decisions and implications of ITS technologies have left considerable room for disagreement. There are several modeling efforts underway; however, each requires considerable additional work to meet the functional requirements and the objectives of FHWA. The near-term (by the end of CY 95) availability of modeling capability with strong technical foundation is very unlikely if not impossible no matter what monies are spent.

Given enough time and money, however. each of the options presented in Section 6 are capable of providing the required framework and the modeling capabilities. The general issue is tradeoff between cost. time. and technical issues. In addition. there are several technical issues that must be resolved at the onset. For example:

Correcting discrepancy between the emissions and fuel consumption estimates of the planning models versus the operational models:

Independent verification and/or validation of the transportation and impact models:

approaches for travel demand modeling: and

user-interface. data requirements. and computational efficiency:

In my opinion, the best courses of action for FHWA are as follows:

1. For the near-term operational capability, the FHWA should continue either the MITRE's (INTEGRATION + THOREAU + Planning Models + User Interface) effort or the VNTSC effort (of course with new models). Given the level of effort involved, I am not quite sure what capabilities can be supported in the near-term with either of these efforts. It is my understanding that MITRE is continually updating the INTEGRATION and THOREAU models as part of the ITS Systems Architecture effort. For example, MITRE has integrated a mode-choice model with INTEGRATION. I am not sure of the current status of the VNTSC work. It might be best advised to seek input from these two organizations to determine real possibilities in the near-term. To be objective, the FHWA must also seek independent assessment of the utility of these two efforts to date and their potential continuation.

   For the mid-term operational versions for the JPO as well as for MPO, I recommend that the FHWA pick one of the four options: DYMOD, DYNASMART. MITTNS, and TRAF). **This could be funded as a 2-year effort. My estimate of cost is $2 M. ORNL** is currently working with each of these four entities as part of the DTA effort. Therefore, a modification to the DTA contract and work under ORNL technical management might be a good idea. The Government could realize substantial cost and time savings under such an arrangement.

   This mid-term capability might seem like duplication of effort and it indeed is. This mid-term capability could back-up the near-term models if they are not as useful as required by the FHWA and/or MPOs and if they are not technically up to par. On the other hand, this work could feed into the long-term modeling efforts such as TRANSIMS and provide additional interim capabilities for that effort than currently planned.

3. While this study is focused towards estimating ATMS/ATIS benefits at a regional level, it might be also useful to estimate the expected national benefits for various types of user services. Such benefits could be derived by the application of the framework in statistically sampled locations. This is my personal opinion as well as a strong suggestion from Prof. Sinha (Purdue) and Dr. Bronzini (ORNL).

4. Similarly, a long term data collection program at the national levei to monitor travel behavior and associated travel impacts should be a priority of the FHWA.

5. Coordination and communication is desperately needed between various offices of the FHWA. In the past. four different offices of the FHWA have supported the modeling efforts. Unfortunately. the coordination of these efforts has been less than would be desired. While it is good to continue work on parallel tracks using different approaches. there is always the possibility of underlaps (such as what is evident now for the benefits assessment framework) and gaps.

6. For the long-term modeling efforts such as TIXANSIMS, the FHWA is best advised to utilize the models/algorithms developed from other on-going efforts to minimize the duplication of effort as much as possible and practical.

7. The non-FHWA funded efforts also should be carefully monitored to avoid further duplication of work.

ACKNOWLEDGEMENTS

The author wishes to thank the following individuals who contributed to this report by commenting on the first draft as well as providing input for their portions of on-going modeling work: Dr. Frank Southworth. Dr. Mike Bronzini. Dr. A. Halati. Prof. Hani Mahmassani, Prof. Kumares Sinha. Prof. Moshe Ben-Akiva. Fred Ducca. Mel Chesiow, Al Santiago, and Ammar Kannan. The author also wishes to acknowledge the timely receipt of the referenced reports from Dr. Walter Gazda of VNTSC and Rich Glasso of the MITRE Corporation.

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Table 1.
Major IVHS Concepts
(Source: VNTSC Report, pg. 1-2)

(ATMS): Advanced Traffic Management Systems	(ATIS): Advanced Traveler Information Systems	(APTS): Advanced Public Transit Systems
Focus: Real-Time, Traffic Responsive Highway Traffic Control	Focus: Real-Time, Traffic Responsive Traveler Information	Focus: Application of IVHS Technology to Public Transit Operations
Detection and Surveillance • Loop Detection and Closed Circuit Television (CCTV) • Beacon Based Communication Systems • Environmental Sensors • Video Imaging Detection Systems (VIDS) **Traffic Flow and Volume Control** • Traffic Signalization Isolated Intersection Control Systems Fixed-Time Coordination Partially Adaptive Coordination Systems Fully Adaptive Coordination Systems Fourth Generation Systems Bus/HOV Signal Preemption **Ramp Control/Ramp Metering** • Freeway Ramp Control/Ramp Metering • Ramp Metering/Arterial Signalization Coordination • Bus/HOV Ramp Bypasses	**Information Dissemination** • In-Vehicle Information Systems - Real-Time Information - Vehicle as Traffic Probe - Route Planning - Dynamic Travel Time Information • Activity Center Kiosks/Monitors/Displays - Major Workplaces - Shopping Centers - Transit Stations • Traffic Information Broadcasting - Television - Commercial Radio Stations - Teletext - Personal Computer - Highway Advisory Radio (HAR) - Automatic Highway Advisory Radio (AHAR) - Radio Data System (RDS) • Changeable or Variable Message Signs (CMS or VMS) **Navigation Systems** • Dead-Reckoning and Map Matching • Dead-Reckoning with Real-Time Information • Route Guidance Systems **Automatic Vehicle Identification (AVI) and Automatic Vehicle Location (AVL)** • One-Way Communication from Vehicle to Reader Unit • Two-Way Communication Between Vehicle and Reader Unit • Electronic Toll and Traffic Management (ETTM) • Automatic User Identification • Implementation of Area Fees and Tolls	**Automation of Operations** • Operations Software - Network and Operations Planning - Vehicle and Crew Scheduling - Marketing, Management, and Administration • On-Board Computers - Fleet Management - Vehicle Utilization and Driver Productivity - Communication with Beacons or Central Computer • Smart Cards - Automated Toll Collection and Parking Fee Billing - Identification of O/D Patterns - Fleet Management • Automatic Vehicle Identification (AVI) - Signal Preemption - Passenger Information Services - Management of HOV Facilities/Preferential Parking • Automatic Vehicle Location (AVL) - Implementation of Area Fees or Tolls - Vehicle Scheduling - Satellite Tracking of Vehicles • Automatic Vehicle Monitoring (AVM) - Monitoring Vehicle Status/Driver Behavior - Demand-Responsive Dispatch/Recall of Vehicles • Paratransit Dispatching Services - On-line Demand-Responsive Scheduling - Innovative Fare Collection - Direct Access for Passenger Service Requests - Fleet Management **Preferential Measures for HOV Vehicles** • HOV Lanes • Selective Traffic Signal Timing/Parking Spaces • Bus/HOV Ramp By-Passes

Table 2.
Behavioral Responses to IVHS Technology
(Source: VNTSC Report, pg. 1-4)

BEHAVIORAL RESPONSE	IVHS TECHNOLOGY
Route Choice	
• Shift to lower impedance route	
- because of information	**ATIS, APTS**
- because of changed impedance	**ATMS, ATIS, APTS**
- because of instructions	**ATIS**
Time of Travel	
• Change in Departure Time	
- because of change in impedance	**ATMS**
- because of change in information	**ATIS, APTS**
- because of instructions	**ATIS, APTS**
Mode Choice	
• Shift to lower impedance mode	
- because of change in impedance	**ATMS, APTS**
- because of information	**ATIS, APTS**
• Shift to HOV facility	
- because of change in impedance	**ATMS, APTS**
- because of change information	**ATIS, APTS**

Table 3.

Evaluation of Current Modeling Efforts to Assess ITS Benefits

CAPABILITES	**DYMOD**	**DYNASMART**	**INTEGRATION**	**NISS**	**MITTNS/DYNA**	**THOREAU**	**TRAF**	**TRANSIMS**	**VNTSC**	
Transportation Network Representation:										
Highway network down to minor arterial	X	X	X	X	X	X	X			
Mass transit system		X					X	X		
Representation (complete and faithful) of ITS Technologies and User Services:										
ATMS							X			
ATIS	X	X	X	X	X					
CVO										
Modeling effect of ITS Technologies on:										

CAPABILITES	DYMOD	DYNASMART	INTEGRATION	NISS	MITTNS/DYNA	THOREAU	TRAF	TRANSIMS	VNTSC	
Trip generation								X		
Mode split								X		
O-D matrix		X	X	X	X	X		X	X	
Trip departure time	X	X							X	
Trip chaining									X	
Route selection		X	X		X					
Representation of Dynamic Aspects of Traffic Operations:										
Spillback	X	X	X		X		X		X	
Incidents	X	X	X		X		X		X	
Merging and weaving		X	X		X		X		X	
Trip departure time	X									
Traffic assignment	X	X	X		X				X	

Table 3: Evaluation of Current Modeling Efforts to Assess ITS Benefits (continued)

CAPABILITES	DYMOD	DYNASMART	INTEGRATION	NISS	MITTNS/DYNA	THOREAU	TRAF	TRANSIMS	VNTSC	
Representation of Traffic Network Operational Features:										
Signals	X	X	X		X	X	X		X	
Ramp metering		X	X		X		X		X	
Changeable message signs		X	X		X		X		X	
High-occupancy vehicle lanes	X	X	X		X		X		X	
.										
.										
Representation of Traveller’s Response to Information		X	X		X					
Provides Impact Assessments and Data On:										
Fuel Consumption	X	X	X				X	X	X	
Air Quality (Emissions)	X	X	X				X	X	X	
Accidents									X	

Table 3: Evaluation of Current Modeling Efforts to Assess ITS Benefits (continued)

CAPABILITES	DYMOD	DYNASMART	INTEGRATION	NISS	MITTNS/DYNA	THOREAU	TRAF	TRANSIMS	VNTSC	
Friendly User Interfaces:					X		X			
GIS	X								X	
Automated Component Model Linkage									X	
Availability on Conventional Workstations	X	X	X		X	X	X		X	
Computationally Efficient	X	X	X		X				X	
Prototype Availability (in next 12 months)	X	X			X		X			

Table 3: Evaluation of Current Modeling Efforts to Assess ITS Benefits (continued)

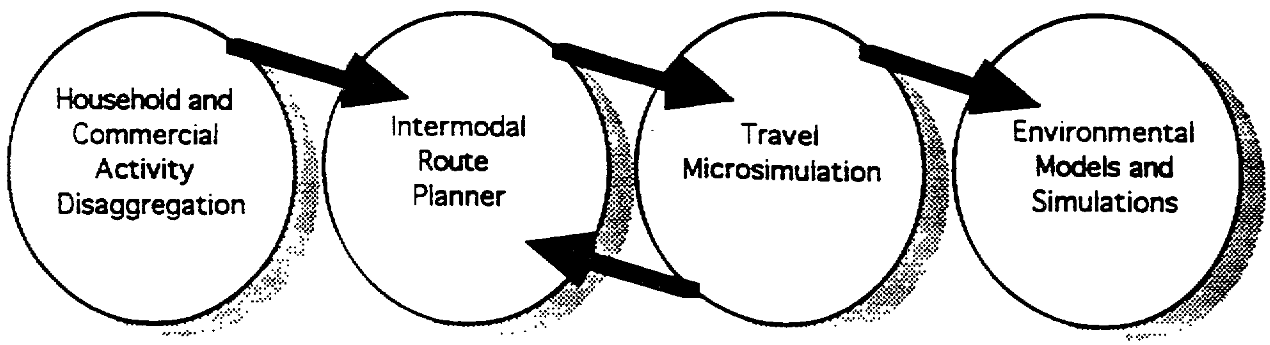

FIGURE 1

TRANSIMS' CONCEPTUAL FRAMEWORK

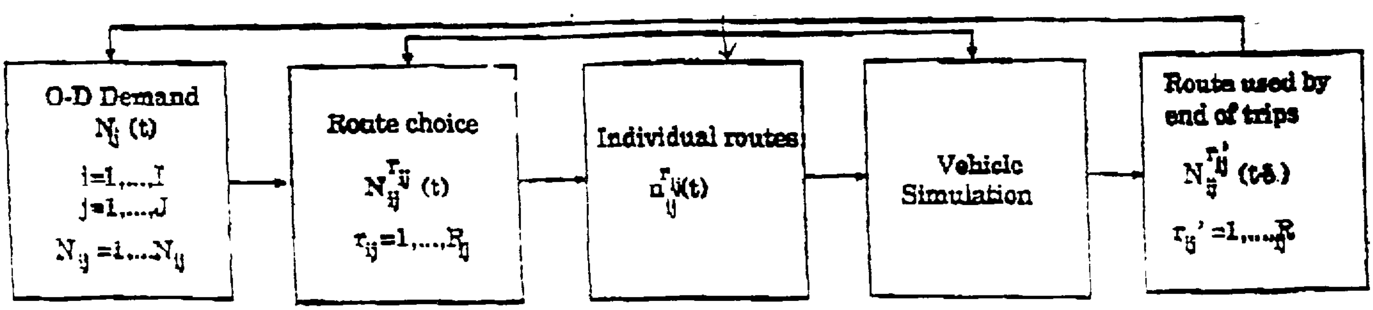

FIGURE 2
NISS' CONCEPTUAL FRAMEWORK

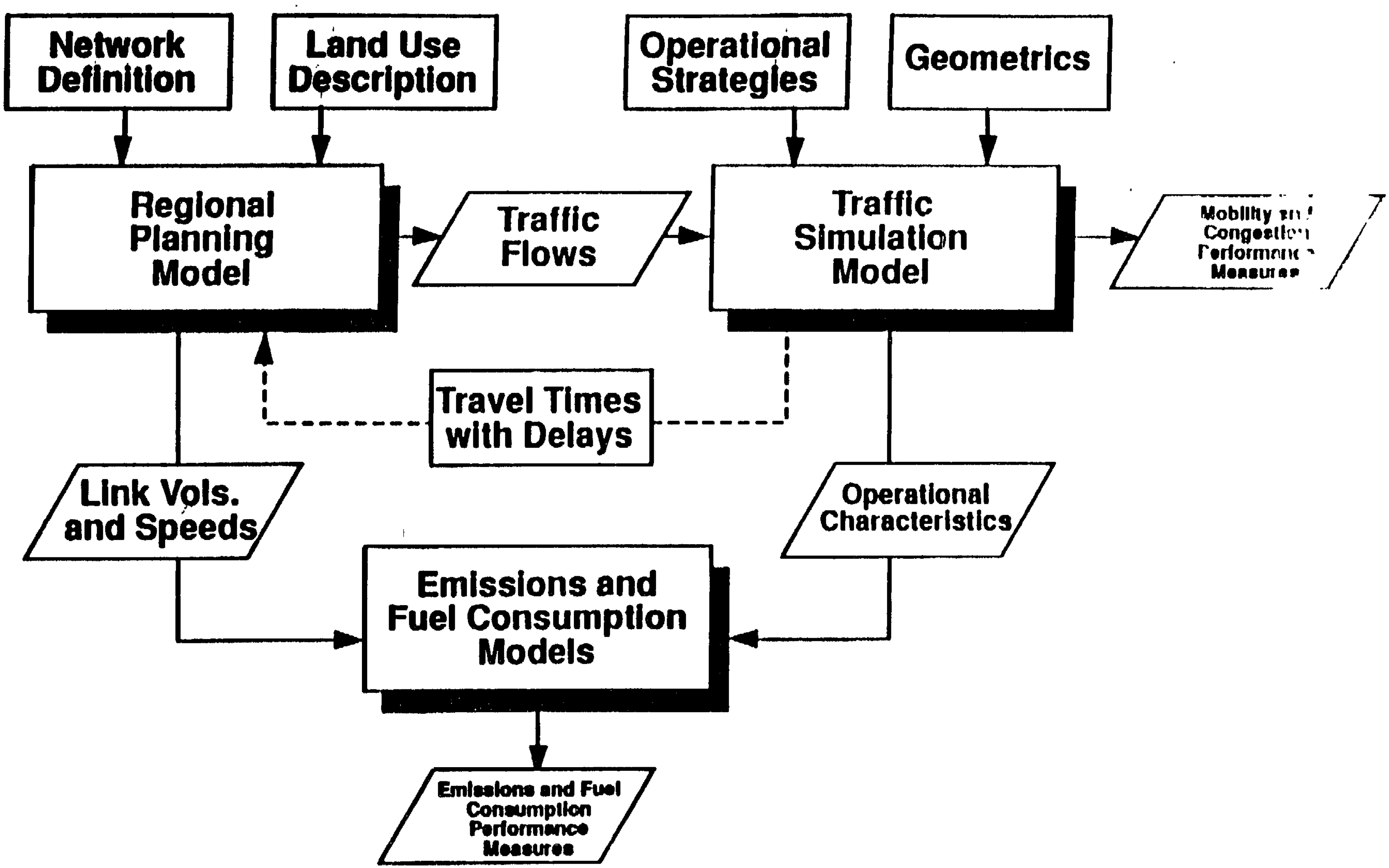

FIGURE 3
VNTSC'S CONCEPTUAL FRAMEWORK

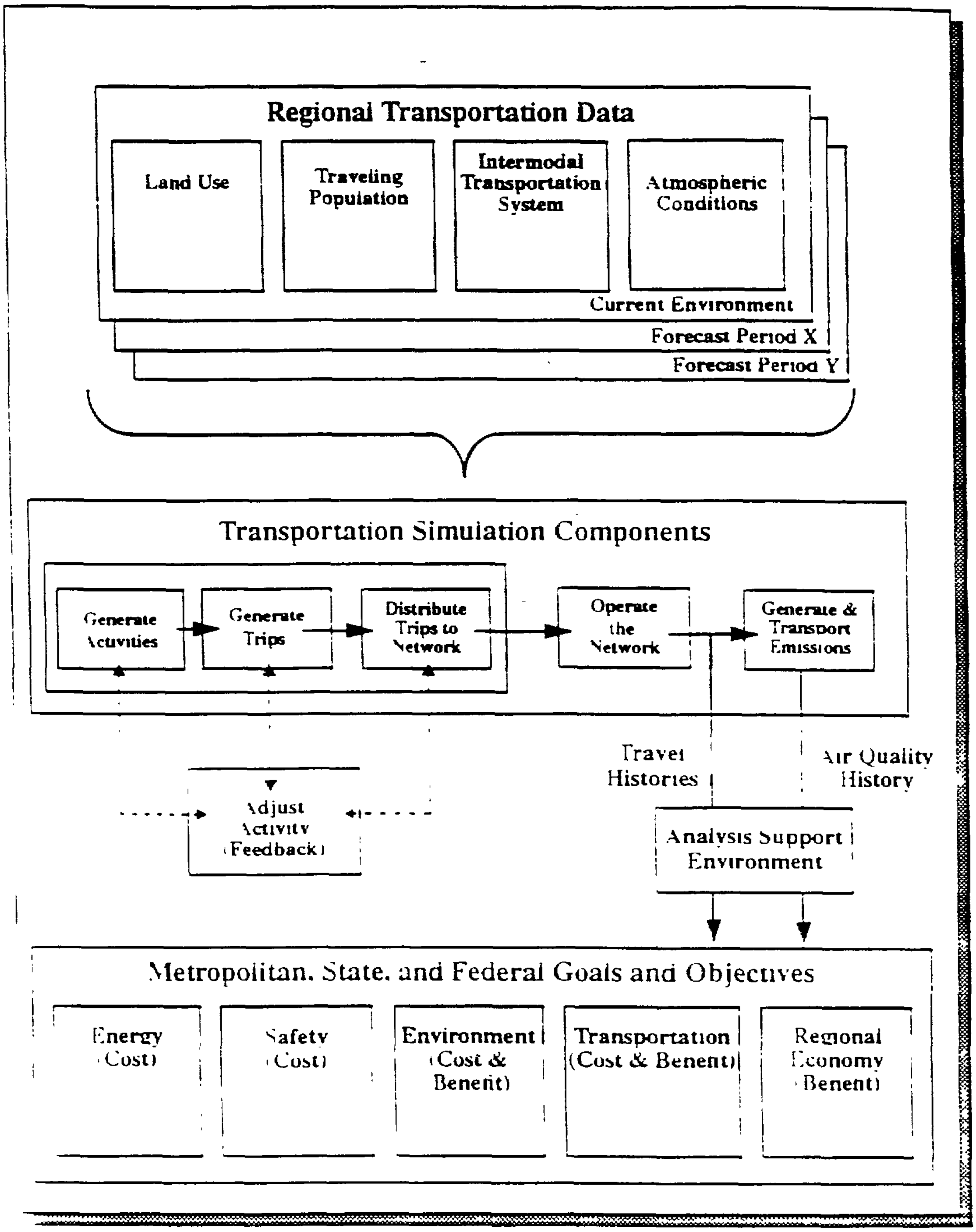

FIGURE 4

TRANSIMS' MODEL SYSTEM STRUCTURE

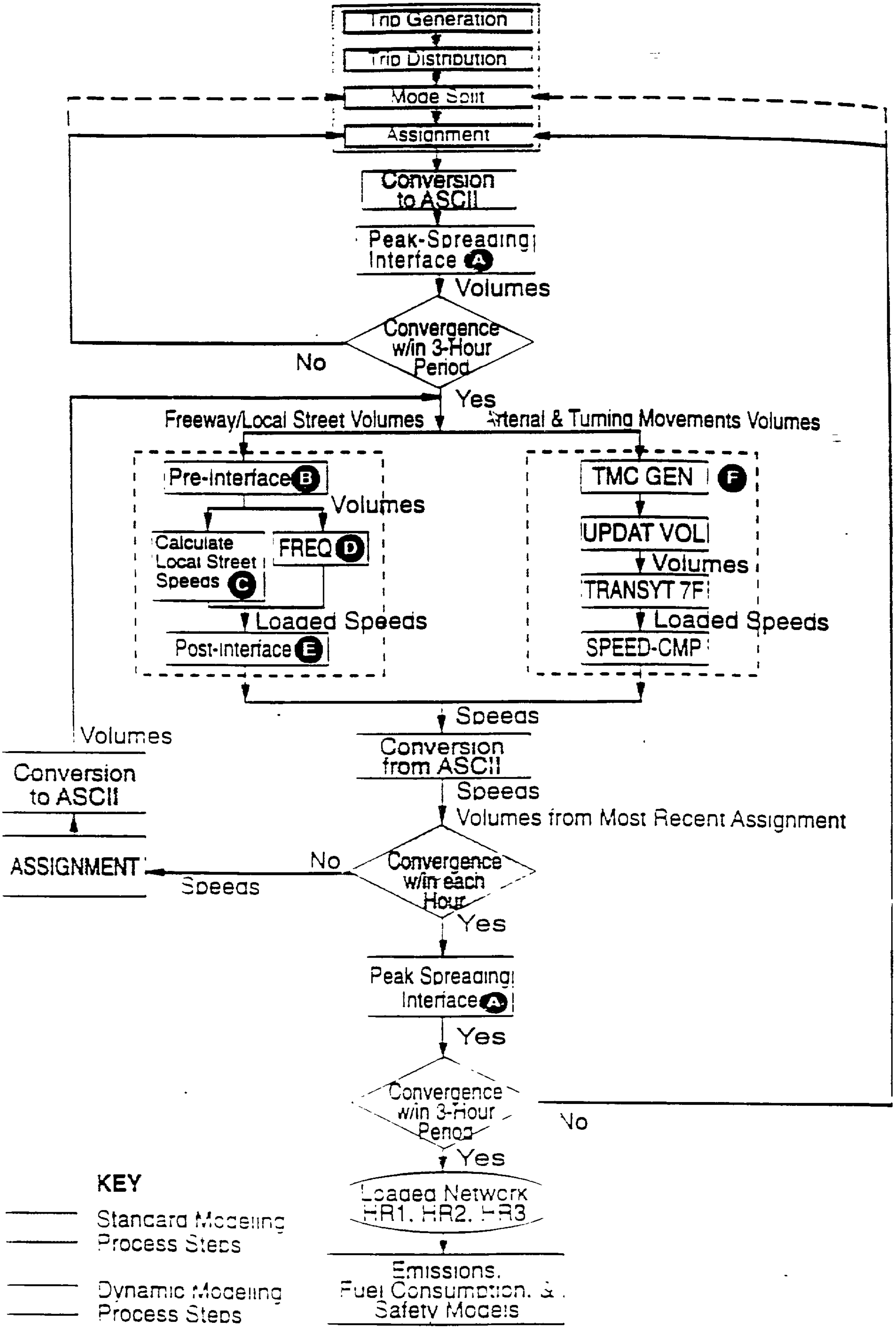

FIGURE 5

VNTSC'S MODEL SYSTEM STRUCTURE

Appendix A: Short Proposal Ideas and Discussions

PURDUE UNIVERSITY

August 8, 1995

JOINT HIGHWAY RESEARCH PROJECT

Ajay K. Rathi, Ph.D.,P.E.
Center for Transportation Analysis
ITS Research Group
Oak Ridge National Laboratory
Martin Marietta Energy Systems
P.O. Box 2008
Oak Ridge, TN 378314206

Dear Ajay:

I appreciate the opportunity of commenting on your write-up. The stuffs that you are attached.

A major part of our activities at Purdue has been in the area of benefit evaluation. The models developed by us and some adopted from already available sources, are being put together with explicit consideration of ITS impact estimation. The Northern Indiana corridor is our primary focus. but we also intend to eventually apply our framework to Indianapolis.

As you may know, the Borman Corridor in Northern Indiana is a part of the Gary-Chicago-Milwaukee Priority Corridor and in Indianapoiis an early deployment study is underway. We have also undertaken extensive research work on air quality modeling with a view to develop a capability to assess the ATMS/ATIS impacts on air quality. We have a separate research project currently in this area, with emphasis on ozone.

What we send to you is in keeping with the thrust of your write-up. I personally, however. feel that we need to conduct a study not simply to develop the capability of estimating ATMS/ATIS benefits at a regional level, but to apply the approach in statistically sampled locations and estimate the expected national level benetits for various types of user services. I also would like to see a long term data collection program at the national level to monitor travel behavior and associated impacts related to ITS.

You should know the people who are involved in the Purdue ITS Benefit Estimation Team. It includes the following people: Samer Madanat, Ph.D. from MIT with Moshe Ben-Akiva as his advisor, expertise is in demand modelling; Srinivas Peeta, Ph.D. from the University of Texas - Austin with Hani Mahmassani as his advisor. looks after the network analysis and DTA part: Andrzej Tarko. Ph.D. from the University of Illinois - Chicago with Nagui Rouphail as his advisor. expertise in traffic safety and control: Pat McCarthy,

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Associate Professor of Economics; Thomas Kuczek, Professor of Statistics; and Robert Jacko, Professor of Environmental Engineering (air quality). My role is to coordinate our efforts and to keep the big picture in view.

Again, thank you for the opportunity.

Sincerely yours,

Kumares

Kumares C. Sinha
Director

KCS/mj

FRAMEWORK AND MODELS FOR THE EVALUATION OF ITS BENEFITS

Abstract

Purdue's framework for ITS benefits assessment diverges from methodologies that aim at generating consistency between short-term DTA models and the traditional long-term planning models. Instead, it uses disaggregate models to determine short-, intermediate-, and long-term impacts of ITS technologies by considering the fundamental variables that cause each of these impacts. Thereby, various disaggregate models are proposed for each of these time frames that consistently feed into an overall framework that incorporates a DTA-based detailed simulation framework at the base level. We feel that such an approach has inherent advantages in the context of ITS impacts evaluation by providing the flexibility to analyze the impact of any parameter on short-, intermediate-, and long-term system performance. It circumvents the rigidity imposed by the confines of existing planning models in identifying fundamental parameters that influence medium-term and/or long-term impacts. For example. by including a disaggregate model for trip frequency in order to assess long-term impacts. one can test the sensitivity of household daily number of trips to ITS benefits obtained in the short run.

Framework and Models for the Evaluation of ITS Benefits

1. Economic Framework for the Evaluation of ITS Benefits

Anticipated benefits from ITS technologies will be generated by significantly different shifts in both the demand and supply of transportation, in the short, intermediate and long terms. In order to appropriately model and forecast these benefits, it is essential to start by analyzing the economic framework within which these shifts take place.

Short Term

In the short term, ITS benefits are generated from improvements in the supply side, i.e., in transportation network conditions resulting from ATMS/ATIS implementation, with few changes in the demand side. These improvements are represented in Figure 1 by a shift in the supply curve from Sl to S2, leading to an equilibrium at a lower travel cost. In the short term, total travel demand in a region or urban area is fixed as travelers do not adjust their long term mobility and travel decisions to the changing performance of the transportation network. This is represented by the vertical demand function in Figure 1. The only likely short-run demand changes are in route and departure time choices. Short term effects start during the course of a day and continue up to one month or so after the implementation of ITS technologies.

Intermediate Term

In the intermediate term, users adjust their travel decisions to the changes in network conditions, through a variety of shifts in mode and destination choice and trip frequency (for non-work trips), in addition to the snort term adjustments described earlier. Shifts in mode and trip frequency lead to an increase in total travel demand. Graphically, this is represented by a flattening of the demand curve as shown in Figure 2. leading to a new equilibrium at a higher level of travel cost than in the short term. Intermediate effects take place during a period of one month to one year approximately.

Long Term

In the long term, we expect to observe further flattening of the demand curve due to shifts in mobility decisions by travelers. such as changes in automobile ownership. as well as changes in residential or workplace location, which translate into substantial increases in trip generation. Of course. short and intermediate changes in travel decisions may continue to take place over the long run. Figure 3 depicts the long term equilibrium and benefits, which are expected to start after about one year of the implementation of ATIS/ATMS technologies and continue until the end of the analysis period.

2. Model System for the Evaluation of ITS Benefits

Current efforts by some research teams attempt to evaluate ITS benefits by aftificially connecting planning models with DTA models. Such an approach has many disadvantages, including lack of compatibility between the model components, inappropriate treatment of the intermediate stage between the transient analysis of DTA and the steady-state models of transportation planning, etc. Rather than pursuing such an awkward approach, we propose to develop an integrated model system and to use it as our primary tool in the benefits evaluation process. This will allow us to directly analyze the various impacts of ATMS/ATIS technologies over the desired planning horizon.

Our model system, depicted in Figure 4, consists of a hierarchy of disaggregate choice models ranging from long-term household location decisions to lower-level travel choices that are made on a daily basis. All the components in this system are disaggregate choice models, in the sense that they represent the choices made by individual households or travelers; they. are therefore based on rigorous transportation demand theories and techniques. These models are inter-reiated through two types of linkages. First, Iower level models take the output of higher level models as deterministic inputs; in other words, longer term decisions are taken as fixed in lower choice models. Second, the outputs from lower level decisions feedback into higher level models in the form of average utilities: in other words, travelers' expectations and experiences are used as inputs in the higher choice models.

At the bottom of the model system is a set of impact models that will be used to predict traffic congestion, crash rates, vehicle emissions and energy consumption. Therefore, the effect of changes in location, mobility or travel decisions by households and users on these measures of effectiveness can be accurately predicted. The development of this model system is well within the capabilities of the Purdue team. In fact, several component models have already been developed. or are currently under development, as part of existing research efforts at Purdue University and elsewhere. This includes behavioral models of route, departure time and mode choice that explicitly account for the effect of traffic information as, well as state-of-the-art DTA models.

3. Benefits Evaluation Procedure

The evaluation procedure will be based on large-scale simulations, using the proposed model system. Due to the need to predict the short, intermediate, and long term impacts of ATMS/ATIS technologies we propose to perform the evaiuation through two sets of simulations having different levels of detail as described below.

Stage 1: Short to intermediate term benefits evaluation

This stage is based on simulating the various impacts of lower and higher-level travel choices made by travelers, for a duration of 12 months. During this period, location and mobility decisions are assumed fixed and therefore the corresponding models are not activated. The simulation time step is 1 day. At the start of each day, the lower level choice models, including the DTA model, are activated and the resulting impacts are modeled through the appropriate traffic flow, vehicle emission, fuel consumption and crash models. After each month, the average value of the utility functions resulting from travelers' daily choices are used as feedback into the set of higher level travel choice models. Thus, travelers' experiences are used to update their higher level choices. The resulting changes in trip frequency, mode and destination choices are then fed-forward all the way to the level of the DTA model and their impacts are simulated. Therefore, 12 updates of these higher level travel choice models are performed in Stage 1.

Stage 2: Intermediate to long term benefits evaluation

This stage is based on simulating the higher level travel choices, mobility and location decisions of households, for a duration of 5 to 10 years. The level of detail at this stage is coarser than that during stage 1. This is necessary due to the longer analysis period, and is reasonable given the increasing uncertainty in the predictions resulting from a longer forecasting period. The simulation step is 1 month. The changes in lower-level travel decisions during each month are approximated by the difference between the first and last days of that month. In other words, all the travel choice models are run jointly, once for each month. At the end of each 13 month period, the average utilities resulting from these travel choices are fedback into the set of mobility and location decision models. The resulting changes in housing or empioyment location and car ownership are then fed forward all the way down to the level of the DTA model and their impacts are simulated.

When both evaluation stages are concluded. statistics on congestion, crash rates, vehicle emissions and fuel consumption will be collected and analyzed by the research team. Differences between the values of these measures of effectiveness under various ATMS/ATIS deployment scenarios and their corresponding values under the null alternative (no ITS deployment) will provide an estimate of the benefits of ITS technologies.

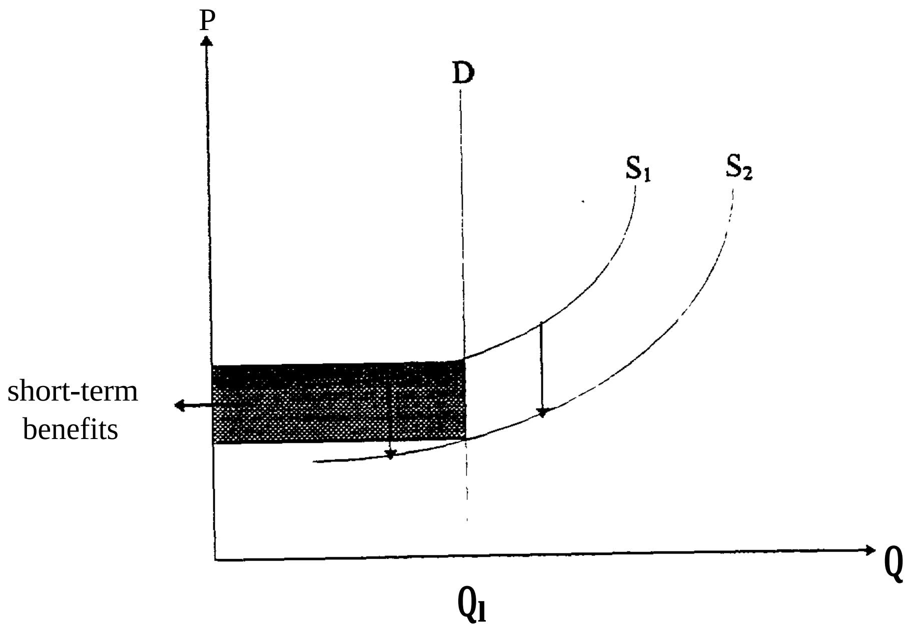

Figure 1 Short Run Benefits

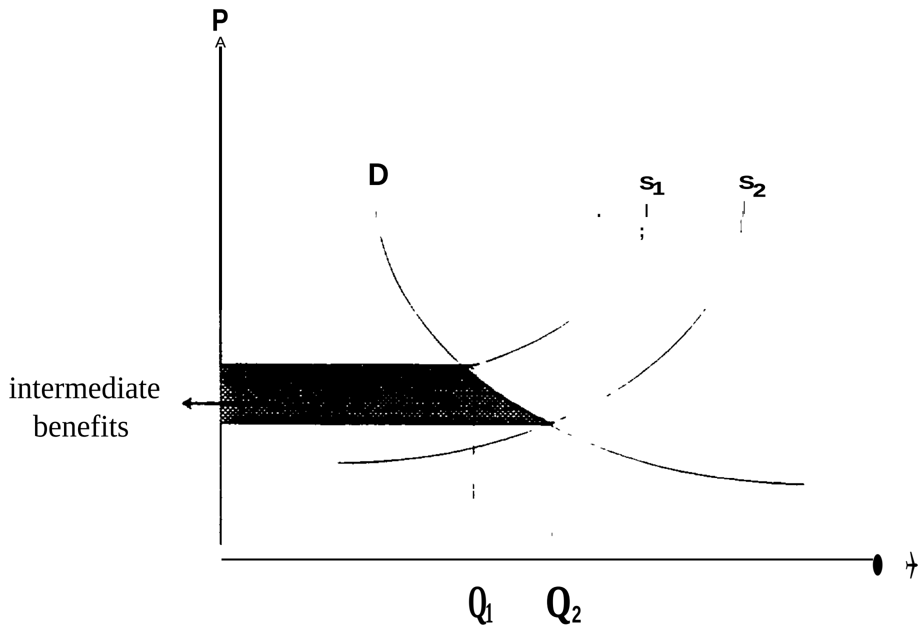

Figure 2 Intermediate Benefits

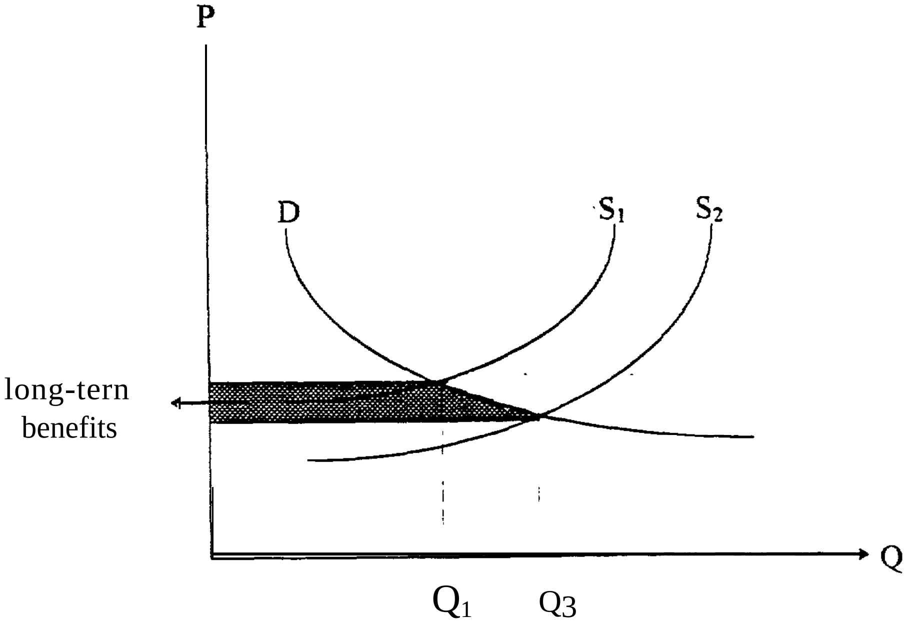

Figure 3 Long Run Benefits

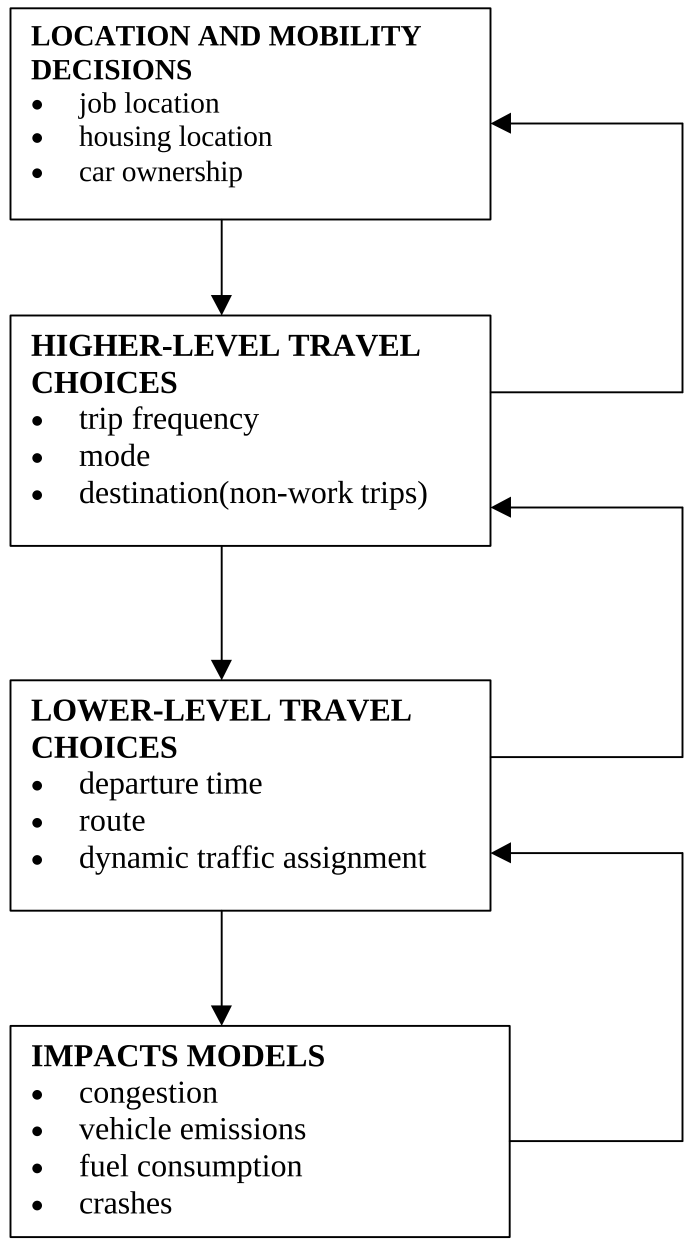

Figure 4 Evaluation Model System

Discussion Paper from The University of Texas at Austin
on DYNASMART

USING DYNASMART AS PART OF A CIMPREHENSIVE EVALUATION TOOL FOR ITS STRATEGIES

Hani S. Mahmassani
The University of Texas at Austin

DYNASMART(Dynamic Network Assignment Simulation Model for Advanced road Telematics) is a state-of-the-art simulation-assignment modeling framework specifically conceived, designed and developed to evaluate transportation networks under ITS strategies, especially real-time information provision strategies (under ATIS) and traffic management actions (ATMS). As such, DYNASMART has been conceived around the three basic elements inherent to such an evaluation: user behavior rules, traffic simulator, and network path processor. It is intended to allow the representation of a wide array of proposed or as yet unthought of strategies with limited modification to the core of the model. For instance, user behavior rules can be changed to reflect evolving knowledge in this important field; traffic control logic at signals or for ramp metering can be readily changed and enhanced to test new proposals.

Recognizing that ITS impacts take place over different times frames, the DYNASMART simulation-assignment model has been incorporated in a day-to-day evaluation framework, allowing investigation of the evolution of system performance over time, as users learn from their experience with the system, as well as under the influence of real-time information strategies and responsive traffic control measures. Similarly, the system controller will learn and adjust to evolving flows in the network. This dynamic interaction taking place over time and space will determine which strategies are effective and which will fail.

The modal allows computation of an array of performance measures, with strong emphasis on traffic operational measures, as well as environmental and economic considerations.

DYNASMART is a natural tool to use in the context of comprehensive evaluations of ITS systems and architectures. It is flexible and adaptable, and readily lends itself to the kinds of modifications and enhancements that arise in connection with broader evaluations. Modifications are suggested in three categories: short medium and long terms, corresponding to the required development time and relative time criticality. Short term refers to 6 to 18 months to 5 years, while everything beyond 5 years is considered long term. Two main uses for the resulting tools are considered: operational and planning/evaluation. While operational needs often require more representational detail than broader evaluation capabilities, the differences in the case of ITS strategies are rather blurred. Without faithful representation of the operational characteristics of the strategies, it is not possible to perform proper evaluations of ITS strategies, even for planning purposes. A third category of proposed development activities consists of evaluation framework research activities. These correspond to the overall concerns that must be addressed in ITS evaluation, including definition of performance measures, considerations of multiple conflicting objectives, recognizing the political nature of the process in which evaluation takes place, as well as the inherent uncertainty in all future planning activities.

Short term

Evaluation Framework Research

- develop appropriate performance measures in a multicriteria framework
- develop strategies for capturing social preferences for ITS impacts
- conceptual approach for evaluation under uncertainly

Tool modification

for operational purposes:

- improve ATMS strategy representation
- improve representation of detailed hardware aspects (e.g. location of sensors and detectors)
- enhance representation of user decision rules
- incorporate capability to generate and test incident prediction and detection algorithms
- incorporate capability for multimodal/intermodal path processing
- develop capability for safety evaluation
- enhance emissions and energy consumption model applicability by using most recent and comprehensive data available

for planning purposes:

- refine day-to-day user decision rules and framework, and expand to incorporate mode choice
- integrate with activity-based travel behavior module: DYNASMART to provide network modeling capability in which trips are generated according to a trip schedule generator (as developed by TRANSIMS).
- develop streamlined yet representationally accurate versions for faster execution on PC platforms
- interface with GIS

Medium term

represent traffic interactions between human-controlled and computer-controlled vehicles with various automation capabilities (automated highway concepts)

capture substitution and complementarity effects between tripmaking and telecommunications use (i.e. teleshopping instead of making a trip).

refine user decision rules10 reflect continuing developments in human factors

obtain data to calibrate key model relationships

provide basic mechanisms to represent land USC interactions

Long term

incorporate land use and spatial activity patterns impacts in analysis tools

perform additional data acquisition and model calibration, especially of longer term impacts

tie simulation explicitly with actual experiments and operational tests

END

Discussion Paper from Viggen Corporation on TRAF

INTRODUCTION

Viggen Corporation is pleased to prepare this idea proposal for "'Models to Evaluate Potential ITS Benefits" in response to ORNL's request. The proposed approach is based on enhancements to the TRAF model that will allow for both the short- and long-term assessment of the planning and economic benefits of ITS. The conceptual framework employs a modular approach. as depicted in figure 1. that combines the most effective and time-proven modeling methodologies into a coherent and comprehensive system. Many of the components of the proposed system such as ITRAF (graphical user interface for TRAF model), CORSIM-GIS, planning models, and TRAPHIX (graphical animation and output display for TRAF model) are already well developed and tested. The framework is based on the TML II architecture. an on-going. FHWA project involving system design efforts to support the development. testing and evaluation of ATMS strategies. and hence can be fully implemented under existing TML II design and thereby virtually eliminating all needs for system design and system integration activities.

At the core of this proposal is the enhancement and implementation of the TRAF family of models. TRAF is an evolving system that was developed by FHWA and represents more than two decades of maturation and advancement in traffic simulation modeling. Traf model can be easily enhanced to incorporate the rapid growth of ITS research and modeling requirements. particularly in the area of ATIS, with minimal efforts related to model structuring, logic enhancements. and theoretical approaches. A number of new models — such as DYNASMART (university of Texas at Austin), MITTNS (MTT Traffic Network Simulator). DYMOD (University of Colorado). TRANSIMS. INTEGRATION, and THOREAU — have emerged with ATlS modeling capabilities and with an emphasis on dynamic traffic assignment. None of these models. however. can match the extensive traffic flow simulation capability of the TRAF family of models. Some of the new models (such as MITTNS and TRANSIMS) are in their early stages of development. In addition. serious concerns have been raised about the traffic flow simulation capabilities of other models (such as INTEGRATION, DYNASMART and THOREAUF and their capacity to model such ATMS strategies as Real-Time control. None of these models. in their present form satisfy the functional requirements for ITS benefits assessment and they all require extensive further development and enhancement. We believe that it is far less risky to build upon the TRAF model's proven and unparalleledcapabilities intraffic flow simulation and ATMS modeling rather than to rely on enhancement or further development of models with unproven track records, untested capabilities and known deficiencies in traffic flow simulation.

ITS BENEFIT ASSESSMENT MODEL

This section describes the components of the proposed framework of activities. We will gladly expand on this should our proposed approach be deemed acceptable.

GIS User Interface

We concur with the functional requirement of a GIS front-end to support the input data preparation process for the ITS benefit assessment model. Through an internal R&D project. Viggen Corporation has effectively completed the development of the GIS interface Lo the CORSIM component of the TRAF model. CORSIM-GIS works with ESRI's ARC INFO products and support Digital Line Graph and TIGER source tiles. The interface provides the automated coding of link and node characteristics from a digital base map and it can use ISTEA managemenr files to access additional network characteristics. (other capabilities include the srorage and management of data files in a DBMS. the visualization and validation of network charactenstics of a GIS, and the display and analysis of CORSIM output results via the spatial analysts tools provided by ARC INFO.

The existing GIS interface require further development into the TRAF-GIS interface by supporting the CORFLO component of TRAF and the selected regional planning models that are described below.

Regional Planning Model:

Two potential approaches for developing the capabilities of planning models (such as trip generation, modal split, and trip distribution) include (1) the enhancement Of an existing simulation model with these capabilities and thus the development of an integrated system such as TRANSIMS and (2) the use of a modular approach that allows for the interface among existing planning and simulation/assignment models. We recommend the modular approach for interfacing the existing planning models with TRAF because such an approach allows MPOs to continue to use their preferred planning tool. builds on their local experience in planning model applications, and enhances the potential for system adaptability and reliability.

We propose that the initial development include a GIS and simulation interface with commonly used planning tools, such as EMME2. TRANPLAN, and MINUTP. The suggested modular approach allows for the future enhancement and interfacing of other planning models that result from the MPOs' requirements or ongoing ITS research.

The Analysis of Economic Benefits

Most of the existing simulation models provide users with a variety of MOEs that describe the traffic flow dynamics (including travel time. delay. speed. and density) for the simulated network as well as the fuel consumption and pollutant emissions. The models rely primarily on users to conduct a comprehensive analysis of the output. to evaluate the trade-offs between conflicting MOEs (such as reduced speed for improved fuel consumption and air quality), and to estimate the benefits and costs of the various strategies.

We propose the design and development of an analytical postprocessing capability for the TRAF model that assigns economic value to the model's MOEs based on the acceptable guidelines for the costs of travel time. fuel consumption depreciation. oil. and tires. This proposed enhancement — coupled with the additional capability for computing the present and future values of the projected benefits and costs — would allow for the efficient assessment of the economic benefits or' ITS strategies and the comparative assessment of various strategies in terms of a common monetary value.

Simulation/Assignment

To support the modeling of ATIS strategies, the enhancements to the TRAF model would involve a two-part strategy based on the short- and long-term requirements for the assessment of the benefits of ITS. For the short-term assessment, we propose an approach that combines the CORSIM model's detailed microscopic traffic flow simulation and its comprehensive ATMS modeling capabilities with the present state of the art in modeling ATIS strategies. The required enhancements include a path-processing capability, time-dcpcndcnt shortest and K-th shortest path algorithms, dynamic traffic assignment, the modeling of a driver's route choice, in-vehicle navigation systems. rhe modeling of-a driver's response to supplied traffic information. VMS modeling an en-route diversion capability. the modeling of vehicle probes. the modeling of enhanced surveillance systems and dynamic 0-D estimation.

The detailed representation of traffic dynamics is generally less important for long-term planning projects because of the inherent inadequacies in long-term transportation planning and the inaccuarcies in traffic demand forecasting. To provide the model users with a choice between laster execution time with a lower level of detail and slower execution time with a correspondingly higher level of detail particulary for the assessment of long-term benefits, the enhancement of the CORFLO model would allow for the periodic reassignment of network traffic based on the suppiied information (actual or predicted). A simpler version of this approach is currently being used in the FEMA model for regional evacuation planning which was developed by ORNL.

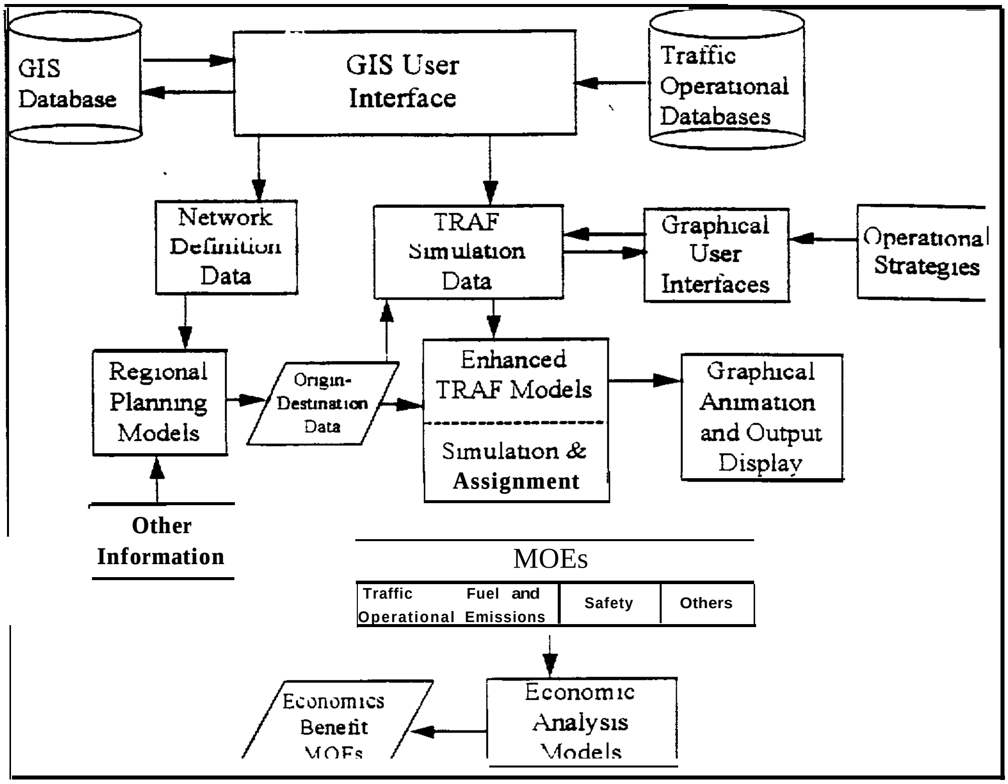

Figure 1. TRAF Framework for Assessing ITS Benefits

Discussion Paper from The University of Colorado/ ORNL on DYMOD

DYMOD.

DYMOD (a Dynamic traffic MODel), developed by Professor Bruce Janson, began its development as an ORNL Director's R&D project in 1989. Continued development since 1991 has taken place at the University of Colorado at Denver with funding from the Colorado DOT and FHWA, and cooperation for data collection purposes from the Denver Regional COG. As described in the 1995 report to Colorado DOT and FHWA by Janson and Robles and in numerous other technical papers and journal articles by Janson and colleagues at ORNL and CU-Denver, DYMOD provides a means of predicting time-varying traffic conditions in reasonably large and detailed urban transportation networks, using actual traffic counts and carefully constructed representations of actual highway networks.

An approach based around DYMOD offers a number of very appealing features when viewed as an ITS (notably ATIS)-supportive transportation planning system:

(i) DYMOD is formulated as a bi-level mathematical programming problem and as such offers an analysis method that is theoretically superior to purely simulation-based models for the purposes of baselining possible ITS (ATIS & ATMS) system benefits. It offers the only currently implemented version of a convergent Wardrop-like traffic equilibrium solution (i.e. convergence to stable solutions can be achieved) for quite large and detailed urban or regional networks. A version of DYMOD has combined dynamic traffic assignment with trip distribution (destination choice) in a theoretically sound manner. Theoretical rigor should be a very important consideration when using a model in regionwide benefit (or benefit-cost) assessments.

DYMOD also offers a number of interesting practical benefits when considered as a planning tool for assessing 5-10 year ITS, and notably ATIS, benefits:

(ii) Recent R&D demonstrates conclusively that under congested conditions. dynamic traffic assignment models yield much closer estimates of traffic conditions than conventional (essentially static) transportation planning models (i.e. more accurate trip distance and speed information, such as would be required for route guidance and traffic impact modeling).

(iii) DYMOD can be used to Integrate destination. route and time of departure choices within a single. consistent modeling framework. The approach is therefore well suited to simulating the effects of pre-trip departure information on congestion levels. Work with a combined distribution-assignment version of DY MOD. initially for network evacuation modeling, focussed on this issue of preferred traveller departure times. Using Pittsburgh data. a method for using traffic counts within DYMOD to re-estimate zone-specific trip departure time profiles was developed.

(iv) The approach is also well suited to the simulation of non-recurrent. incidence based traffic delays. and has given very encouraging results when tested using real data on lane-blocking accidents.

(v)DYMOD has also been used to simulate the impacts of travel guidance on link/path loadings. Given access to sufficiently high speed computing power. it is claimed that DYMOD can be adapted to run with traffic detection devices, to predict evolving traffic conditions in a fraction of real time. A recent application of the model to a 100 square mile, I10 traffic analysis zone, 1714 node, and 3417 link network based on Denver's I-25/HOV Corridor used 5 minute traffic volume counts to simulate 222,218 trips during the 5-10 am travel period.

While larger networks and more frequent traffic counts will need to be handled in actual operational systems, as regional traffic monitoring and control centers come on line this approach should offer increasingly accurate estimation results: and hence more accurate measures of systemwide travel time, cost and safety benefits. The largest application of DYMOD to date (perhaps the largest dynamic traffic assignment ever run) is now being made on a Chicago database. This ADVANCE network, developed by researchers at the University of Illinois at Chicago (UIC) for the ADVANCE ITS project funded by FHWA, is a detailed network covering roughly 400 square miles with 440 traffic analysis zones, 9,500 network nodes and 15,600 links. In this application researchers at UIC have modified DYMOD to use more specific intersection delay functions for the turn movement links. In an application funded by the Illinois DOT this model was run on a CONVEX supercomputer for the purpose of estimating travel delays caused by incidents. In assisting the project Dr. Janson added an option for the user to specify the percent of trips that remain on travellers' usual route -- an important feature for evaluating the benefits of ATIS as well as traffic management strategies.

More importantly, for the purposes of system benefit assessment. the closer the connection we can make between planning models and the models we use in our operational ATIS monitoring and advisory systems. the better off we will be. Ideally, both planning and operational ATIS analysis tools would be run from the same database and data collection system and would use the same dynamic traffic model. In this context the DYMOD approach is a very promising one. as it can be set up to handle the details involved in each of the individual tummg movements that are possible at traffic intersections. while maintaining the representation of traffic as a series of link flow volumes. albeit highly discretized in both space and time. A recent paper by Janson and Robles describes an extension of the approach to a quasi-continuous time formulation. which allows more realistic modeling of spillback queue effects from oversaturated links and non-recurrent events such as accidents.

In terms of the way DYMOD aggregates vehicle movements into traffic flows it remains very much in the traditional style of the mesoscopic traffic assignment models used for years by MPOs. At the same time it has moved a good way towards the level of roadway detail offered by traditional traffic engineering 'microsimulation models'. To be useful at a highly detailed level of network resolution. DYMOD requires extensive database preparation. notably the coding of individuai turn movements as separate links at each intersection. For more regionwide analyses. however. DYMOD's essentially mesoscopic structure makes it possible to simplify this representation of network interchanges and to run the simulation as a more approximate strategic regional planning tool. This dual level of resolution option may prove useiui as a means or' factoring regionwide impact measures up or down on the basis of more detailed and localized traffic analyses (such as incidence analyses) using the same traffic

model in each case.

(vi) A DYMOD-based modeling approach also is also readily extendable to elastic trip generation modeling (perhaps given a certain amount of user interaction in the selection of initial travel cost elasticities), by building on work by the same researchers at ORNL and which led to the Network Performance Evaluation Model (NETPEM): an HOV-lane simulation program developed for US DOE. For example, using traffic count data (see ii above), DYMOD could be adapted to simulate the feedback effects of reporting en-route congestion levels on travellers not yet on the network. That is, a certain percentage of travellers might choose not to make the trip, or at least not to do so within the current peak commuting period.

(vii) Procedures for constructing the detailed transportation networks, as well as setting up the appropriate travel demand and traffic counter databases as used in the Denver applications, were constructed within a commercial GIS software (TransCAD). This GIS software is also used to display the model results. GIS's are now widely recognized as the most effective user environment for future transportation planning studies.

Major areas requiring work take the form of modeling additions to other steps of the transportation planning process. or to attach the existing model to models measuring "external" transportation costs and benefits. In particular:

(i) DYMOD will need to integrate a modal choice subroutine. preferable a nested. multinomial logit model.

(ii) DYMOD will need to link its output to suitable fuel consumption and emissions estimation routines. That is to routines which base fuel use and emissions on vehicle miles of travel by vehicle type operating speeds stop-start traffic conditions (not simulated by static assignment routines) and roadway conditions.

(iii) Since an ATIS-induced decision not to travel during the peak period might lead to an off-peak trip to the same or another destination, DYMOD will need to simulate ATIS benefits throughout a full day. This includes finding a way to include the impacts of ATIS technology on travel-reducing multi-destination trip chaining behavior. No currently operational models do this.

(iv) Along with all other currently operational transportation planning models. DYMOD will need to include explicitly the modeling of commercial vehicle movements within the region of interest. Trucks also engage in extensive daily trip chaining activity, depending on type of commodities carried.

(v) To be user friendly. DYMOD (again. as with other modeling systems) will need. to be more closely integrated into a GIS-based environment in order to supply a user with the necessary decision support aids. Any traffic counter data already in existence could be introduced to the simulation modeling process through this Interface (which could. local area counter communications technology permitting become a real time or periodic automated count collection process: for example, along the lines of the Real Time Traffic Monitoring and Analysis System developed by Dr. Southworth and colleagues for the Federal Emergency Management Agency (FEMA).

Of these requirements (i) and (ii) are readily implementable, recognizing that there is currently no reliable model of on-road emissions production tied to actual traffic conditions. Numbers (iii) and (iv) identify challenging tasks and well known deficiencies in all current transportation planning models at this time. Number (v) also represents a significant area of work, albeit with no theoretical or conceptual hurdles to overcome. This task could benefit significantly from the now extensive expertise at ORNL in developing such GE-based decision support systems for FHWA and other federal agencies.

Discussion Paper from Argonne National Laboratory (ANL)
and Oak Ridge National Laboratory (ORNL)

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Dr. Christine Johnson
Director, Joint Program Office
Intelligent Transportation Systems
Federal Highway Administration
400 Seventh St., SW
Washington, DC 20590

Dear Dr. Johnson:

As you well know, there is keen national interest in the environmental impact of deploying intelligent transportation systems (ITS). In recognition of this, Argonne National Laboratory (ANL) and Oak Ridge National Laboratory (ORNL) have prepared the enclosed two page discussion paper on a methodology to estimate the energy and emissions consequences of the adoption of ITS technologies. This approach builds on research that Argonne and Oak Ridge developed when we collaborated on a joint project that estimated the impacts of energy-efficient transportation technologies for use in urban transportation. That study became a frequently referenced work in urban transportation planning. As a matter of background, Argonne continued to refine the models into an integrated package known as TEEMS (Transportation Energy and Emissions Modeling System). TEEMS was used in the interagency National Acid Precipitation Assessment Program, where it underwent three extensive peer reviews and each time received the highest rating of all the projects under Analytical Procedures for Manmade Sources. Subsequently, *TEEMS* has been used on numerous Department of Energy projects. Working in parallel, ORNL has further developed data bases on the national highway system and automotive travel, and validated them through application in the DOT's biennial highway needs assessments.

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The genesis of the attached discussion paper is twofold. It is now widely recognized that major transportation infrastructure projects are taking as much as six to ten years between initial scoping and final approval, following the Environmental Impact Statement (EIS) process. New planning regulations under ISTEA, especially the formulation of the Major Investment Strategy and the early involvement, under NEPA, of concerned regulatory organizations and public interest groups, are intended to make this process more efficient and perhaps less dilatory; yet the protracted preparation of an exhaustive EIS for each and every major project, including deployment of ITS technology, is still required. This is because there is no programmatic EIS for ITS deployment generally--that is, a document that can be included by reference in project-level analyses, saving time, resources, and duplicate effort. The design and scope of the proposed study provides that its product could form the cornerstone of such a reference document. In a draft White Paper on environmental issues in ITS prepared by the Energy and Environment Committee of ITS America, it was pointed out that "...Environmental groups are looking for good research evidence, based on solid modeling [emphasis added], that ITS will work as advertised without causing the same old set of problems that they have been criticizing transportation systems for in the past." [Draft White Paper for the Intelligent Transportation Society of America. January 26 1995.] To our knowledge, such objective and transferable evidence does not yet exist.

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The other point of departure is the many years of experience shared by ANL and ORNL in the preparation of programmatic EIS analyses and documents. Thus, we are very muchaware of protocols and procedural requirements of the EIS process, having dealt with topics having a very high degree of sensitivity with the public-especially the transportation of hazardous, nuclear, and toxic materials.

Our Argonne/Oak Ridge team would be pleased to meet with you and your staff to familiarize you with our capabilities and determine how this type of effort could fit into your planned activities. We will contast your office soon to arrange a convenient time for a meeting.

Thanks for your interest.

Sincerely,

Larry R. Johnson
Director
Center for Transportation Research
Argonne National Laboratory

Michael S. Bronzini
Director
Center for Transportation Analysis
Oak Ridge National Laboratory

cc Adrian Tenmer, ANL/ITS Coordinator
Ajay Rathi, ORNL ITS Program Manager

ENERGY EFFICIENT AND ENVIRONMENTALLY BENEFICIAL ITS SYSTEM IPTIONS FOR U.S. URBAN REGIONS

Concepts for implementing intelligent transportation systems (ITS) have to date emphasized logistics, technologies, and costs and have in many cases given only secondary (if any) consideration to transportation energy consumption and pollution. No analysis has determined whether there will be significantly greater benefit to the nation from widespread ITS deployment than congestion mitigation and avoidance of expenditun on new lane-miles of roadway. Conventional wisdom holds that there will also be air pollutant mitigation and petroleum conservation advantages to ITS, relative to current infrastructure, that should be included on the benefits side in any cost-effectiveness computation; thus, ancillary savings from reducing health-related lost work days and increasing productivity, coupled with national security cost savings attributable to reduced foreign oil dependence, could make ITS a sensible investment This convetuional wisdom has not yet been systematically questioned or tested.

Argonne and Oak Ridge National Laboratories propose a joint effort to rigorously test the hypothesis that well-conceived ITS projects will uniformly reduce air pollution and petroleum consumption in transportation using a modeling framework with a distinguished history in policy and impact analysis. Fii developed in the early 1980s for the multi-laboratory, multi-university Technology Analysis of Productive Conservation in Urban Transportation (TAPCUT), a comprehensive policy study sponsored by the DOE Office of Environmental Analysis, the Transportation Energy and Emissions Modeling System/Urban Transportation Policy Analysis Package (TEEMS/UTPAP) has been used over the past ten years in a wide variety of consumer choice and activity forecasting applications for General Motors and the National Acid Precipitation Assessment Program, and continues to be used in analysis performed for the DOE Office of Transportation Technologies. It examines urban scale (sketch transportation networks), regional, and national effects. It was one of the first models to posit, then prove, the legitimacy of applying transportation activity, fuel consumption and emissions results and trends for a given urban region across the spectrum of all (U.S.) urban regions sharing key characteristics. In fact, all MSAs in the U.S. can be categorized by the TAPCUT method into one of a very restricted set of urban area types relative to transportation use. This has facilitated the articulation of a national (or paradigmatic) scale of analysis results from a limited set of case study urban regions, thus representing a considerable cost saving without a commensurate sacrifice in precision.

Argonne and Oak Ridge teams skilled in transportation analysis collaborated on the TAPCUT project and have worked together productively on many occasions since. For the proposed effort, it is envisioned that a number of “prototypical” metropolitan areas will serve as the test bed for comparison of several state-of-the-art and emerging ITS designs (the assistance of a panel of experts may be sought for fleshing out the specific components of these designs). Designs finally selected for comparison would be overiaid on the highway networks of the selected urban regions and, using the TEEMS/UTPAP family of choice, activity, network flow, emissions, and energy consumption models, would be subjected to a battery of sensitivity analyses to quantify savings in a) travel time (monetized), b) emissions of priority pollutants and greenhouse gases and c) petroleum consumption. The best designs would then emerge but, more importantly, so would the dimensions of the validity of “conventional wisdom” for purposes of making rational and truly cost-effective decisions about ITS deployment and its role in the national interest. Results obtained for the prototype areas would then be scaled to the national level using Oak Ridge’s transportation network and activity databases.

STUDY CONCEPT

The study proposed here would be undertaken in recognition of two unmet needs in the development of long-range national ITS policy: 1) absence of any systematic analysis of or attention to all relevant effects (primary, secondary, even tertiary) of the implementation of ITS in urban areas. especially with respect to activity generation. emissions, and petroleum savings; and 2) failure to treat the effects that have been considered at the disaggregate personal choice level of decision the level that will determine ITS utilization and ultimate magnitude of success.

In Phase 1 of this study, a set of at least three (but not more than 20) paradigmatic urban regions will be identified by interpretation of the axial loadings of Q-factor analysis (or a similar statistical contingency technique) as applied to Census demographic, employment. income, and travel data for all MSAs. One protyical city will be selected for each of these regional types, and origin-destination (O/D) matrices at the traffic analysis zone (TAZ) level will be obtained from their respective metropolitan Planning Organizations or state Department of Transportation, along with the existing (coded) highway network used for development of the long-range Transportation System Plan. The principal through routes of these networks-Interstates, other freeways, and primary arterials-would be identified as the target corridors for ITS configurations, and would also (in the guise of capacity and distance values in each TAZ through which they pass) serve as the building blocks of the sketch network to be used in the analysis of each city.

In Phase 2 of the study, peak and off-peak capacity-restrained network travel times for the *i j* interchanges of each city's O/D matrix that axe affected by ITS configurations would be modified appropriate to the time savings (from reduced congestion and steadier throughput) attributable to the ITS project. Households in each MSA (each categorized in one of 1712 cells according to five demographic descriptors) would be presented the stimulus of (a) the availability of "intelligent" vehicles in the new replacement car marketplace, defined according to their purchase and operating costs and amenities relative to conventional alternatives. and (b) a choice among urban travel modes that includes use of ITS facilities in personal vehicles. Once these choices are made, new trip demand levels can be estimated and O/D flow volumes reconfigured and assigned to the sketch network with its revised capacity constraints. Phenomena of trip generation and network performance attributable to ITS can thus both be examined.

Phase 3 of the study would involve the actual accounting of energy and pollution savings for each prototype MSA in the analysis. Net travel time savings are translatable into average increase in speed, which in turn results in percentage increase or decrease (for speeds over 45 mph) in vehicular fuel efficiency, and also into reduced or increased exhaust pollution per trip. Insofar as possible, emission and fuel consumption change results would be reported by (a) TAZ (b) vehicle type, and (c) income group (or other more relevant demographic). This phase would also include sensitivity testing of results across a likely range of ITS configurations and assumptions about future average fuel economy and emission rates (including those characteristic of AFVs) by vehicle type.

Phase 4 would comprise the development and application of expansion factors to identify MSA-level changes for each urban area categorized by one of the factor loadings. Confidence limits on these quantified changes in fuel consumption and exhaust emissions will be identified. Again, once common economic, employment, and demographic elements have been identified and factored into the partitioning, the differences in highway network configuration (not accounted for) between each prototype city and all other MSAs within its category are dominated by elements which a r e included in the expansion factors and thus would only minimally affect the results. National- and local-level results for these characteristics will be weighed against ITS implementation and maintenance costs for the configured systems to generate cost-effectiveness values in (a) $ per ton of emissions removed (by pollutant) and (b) $ per barrel of oil saved.

Appendix B
National Institute of Statistical Sciences Infrastructure Project

News form the National Institute of Statistical Sciences

NISS Transportation Project Funded

Alan F. Karr
Associate Director, NISS

NISS has received official notice from the National Science Foundation of funding for a five-year, $6,000,000 transportation project entitled "Measurement, Modeling and Prediction for Infrastructural Systems." Funds for the project come from the Mathematical and Physical and Engineering directorates at NSF.

A cross-disciplinary, multi-investigator effort, the project focuses on scientific and statistical problems affecting surface transportation demand and supply. This focus recognizes the urgent need for restoration. Improvement and expansion of the nations physical infrastructure, a task that has been designated as a high priority need by policy makers at the highest levels of government. Surface transportation systems, which affect safety and the environment as well as the economy are especially important.

Alan F. Karr, Associate Director of NISS, is Project Director; co-principal investigators are Eric I. Pas, Associate Professor of Civil Engineering at Duke University and Jerome Sacks, Director of NISS.

Participants include additional faculty from Duke, North Carolina at Chapel Hill, along with seventeen other universities, government agencies and corporations form the U.S. and abroad. They include P. Benson (California Department of Transportation), C. Bhat (Civil and Environmental Engineering, Massachusetts), P. Bickel (Statistics, California, Berkley), D. Boyce (Transportation and Regional Science and Urban Transportation Center, Illinois at Chicago), D. Cox (Statistics Rice), D. Daley (Statistics, Australian National) P. Goel (Statistics, Ohio State), R. Kitamura (Transportation Engineering, Kyoto), F. Koppelman (Civil Engineering, Northwestern), K. Lawton (Metro Planning, Portland, OR), C. Lula (RDC. Inc.) R. Lytton, Civil Engineering, Texas Transportation Institute). H. Mahmassani (Civil Engineering Texas A & M and Texas Transportation Institute), H. Mahmassani (Civil Engineering, Texas at Austin), D. Naiman (Mathematical Sciences, North Carolina State). O. Pendleton (Texas Transportation Institute), D. Reinke (RDC. Inc.), Y. Ritov (Statistics, Hebrew University, Jerusalem), N. Rouphail (Civil Engineering, North Carolina State). A. Sen (Urban Planning and Urban Transportation Center, Illinois at Chicago), S. Shah, R. Smith, S. Stidham, R. Vitale (Statistics and Actuarial Science, Waterloo), M. West (Statistics and Decision Sciences, Duke), and D. Zollinger (Civil engineering, Texas A & M, and Texas Transportation Institute).

Also involved are more than a dozen postdoctoral fellows and graduate research assistants.

Research thrusts of the project are:

- Travel demand forecasting, especially for urban surface transportation.
- Network modeling for intelligent vehicle-highway systems (IVHS), with emphasis on systems for real-time route guidance and planning;
- Materials science and deterioration of concrete, in order to develop new tools for design of concrete.
- Performance prediction for pavement to produce improved methods for designing and maintaining pavement and other transportation structures.

The research will utilize and develop a variety of statistical techniques that deal with large systems with complex dependencies. Statistics is the enabling technology for characterization and prediction and provides ways to gauge the accuracy and variability of predictions.

Discussion Paper from Massachusetts Institute of Technology (MIT) and Carnegie Mellon University (CMU) on MITTNS and MITSIM

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August 9,1995

VIA FAX AND FEDERAL EXPRESS

Ajay K. Rathi
Oak Ridge National Laboratory
Martin Marietta Energy Systems
P.O. Box 2008
Oak Ridge, TN 37831-6206.

Subject: Models for Assessing the impacts and the Potential Benefits of Intelligent Transportation Systems

Dear Ajay,

Thank you for providing us the opportunity to comment on and contribute to your working paper. Please find enclosed our comments and a brief proposal for a methodology to assess the impacts and potential benefits of ITS. In preparing this material I was assisted by the following individuals: Haris Koutsopoulos, Associate Professor, Carnegie Mellon University; Rabi Mishalani, Research Associate, MIT ITS Program; and by three MIT doctoral candidates: Kalidas Ashok, John Bowman, and Amalia Polydoropoulou.

Please contact me if you have any questions or require further clarification of the attached material.

Regards,

Moshe Ben-Akiva

A Short Proposal for ITS Benefits Assessment Methodology
Prepared by the Massachusetts Institute of Technology
and Carnegie Mellon University
August 9,1995

OVERVIEW

ITS strategies involve real-time operation of transportation system. Therefore, evaluation of ITS strategies should take explicitly into account (1) the dynamic nature of the system and the dynamic interactions between demand and supply, and (2) the inherent stochasticity of transportation systems. The ITS components (surveillance, control and routing, congestion pricing, etc.), travel demand adjustments, and effects of ITS performance on travel behavior and network performance should be represented. One of the biggest challenges of ITS benefits assessment is to link ITS processes, many of which operate dynamically in a real-time environment, with the effects of ITS which occur on much longer time scales. Examples of such effects include the adjustment of activity schedules, travel patterns, auto ownership levels and residential location patterns.

The framework. shown in Figure 1, captures the important characteristics of the problem by using a hierarchical model structure, with each level of the hierarchy operating at different levels of time resolution. The main elements of the framework are:

- **Land Use.** Land use models operate with the coarsest time resolution. predicting changes in employment. residential location and other land uses which emerge over a period of years.
- **Demand.** Demand models include the mobility decisions of households, such as the acquisition of ATIS equipment, and the daily activity and travel decisions of individuals.
- **Dynamic Traffic Assignment.** This model system produces an “average” steady state within-day dynamic distribution of trips given initial time dependent O-D matrices. It operates with time intervals measured in minutes.
- **Dynamic Traffic Simulation.** This traffic simulation. which operates on time intervals measured in seconds. provides a detailed description of ITS characteristics, models emergent network conditions. and captures stochasticity of the system.
- **Resource.** These models use the outputs of the other models to provide information on the effects of ATIS on the environment energy consumption. level of service to travelers and safety.

The first three subsystems together constitute an equilibrium model. with reiteration of the models occurring until assumptions and outputs are consistent across all levels. The model can be solved for equilibrium at several different points aiong the planning horizon to measure the effects of the policies over an extended time period. The equilibrium model subsystem however, does not provide the level of detail necessary for assessing ITS performance comprehensively. Therefore, a more detailed simuiation model is required. Hence at each point the network simulation model takes outputs from the equilibrium model, simulates emergent phenomena feeds back improved capacity information, and supplies performance data at the required level of detail to the resource models. The purpose of the feed-back is to ensure an acceptable consistency between the equilibrium model subsystem and the simulation model. The entire system requires the input of exogenous information at each point on the planning horizon, including forecasts of future conditions which influence the transportation system. such as population growth. Measures of performance available from the system include emissions, fuel consumption. total number of trips, average travel time, etc.

An important feature of the model framework is the explicit representation of traveler behavior and ATMS/ATIS (surveillance, control and routing) in both the network equilibrium and network simulation models. The demand model **also** explicitly represents ATIS related traveler behavior, including the acquisition of ATIS equipment and services.

DESCRIPTIONS OF THE MODEL SUBSYSTEMS

Land Use. Land use models, which predict changes in employment, residential location and other land uses for a given policy scenario, are outside the scope of the research and development effort suggested by the JPO. Under this assumption. this portion of the model system represents the exogenous supply of land use information to the other model subsystems. However. the effects of ITS on land use patterns might be among the important results of ITS implementation. For example. effects such as increased spread of residential and commercial development might occur within a 10 year time frame in response to improved transportation system efficiency. It may be advisable to implement a methodology which can be extended to include land use models. and begin this modeling effort now, so that land use models can be implemented at a later stage in the development of an ITS assessment methodology.

Demand. Land use changes are input to demand models which predict individual mobility activity and travel decisions. Feedback from the traffic assignment model enables the demand models to evaluate the effects of ITS on activity and travel planning, including induced demand. trip chaining. and the effects on the choices of destination. mode and time of day.

Activity and Travel Decisions. The core demand model is an activity based discrete choice model system of an individual's daily activity and travel schedule. The model system represents a person's choice of activities and associated travel as a daily activity pattern overarching a set of tours. The daily activity pattern model predicts the sequence of tours for primary and secondary activities. with one alternative being to remain at home for ail the day's activities. Tour models include the choices of times. destinations and modes-of travel. and are conditioned by the choice of a daily activity pattern. The choice of daily activity pattern is influenced by the expected utility derived from the available tour alternatives. This expected utility depends on travel conditions estimated by the ITS-sensitive network equilibrium model.

Mobility Decisions. The mobility decisions include. among others. awareness of and access to ATIS services and/or equipment, and participation in telecommuting programs. The ATIS awareness model represents how people find out about ATIS, acquire information about available ATIS products and services. increase their knowledge and develop perceptions towards ATIS. The ATIS access model reflects a consumer's willingness to pay for purchasing ATIS devices such as in-vehicle systems or subscribing to services such as telephone information services. The outcome of these models are ATIS penetration rates.

The telecommuting model addresses the process of telecommuting adoption and its impact on the reduction of work trips. Information technology (IT) facilitates various forms of remote work arrangements. providing organization with a wide range of alternatives to address issues such as avaiiability of skilled labor, cost of office and parking space. and traffic congestion. IT provides individuals with electronic-based non-travel access to various types of activities, such as work, shopping, or leisure. The employer's decision to implement telecommuting is a function of expected impacts of the telecommuting program on productivity and costs, and the employee's decision to adopt telecommuting is a function of the potential impacts of the program on her/his lifestyle. work related costs and income. The. outcome of the model is the expected reduction on the number of trips due to telecommuting.

Dynamic Traffic Assignment. Network performance depends on the mobility, activity and travel alternatives which people choose. The dynamic traffic assignment model receives this information from the demand models in the form of time- and mode-specific O-D flow matrices. Separately. a dynamic O-D estimation module estimates a set of time dependent trip matrices using historical information on link volumes. Estimates obtained from this latter model are "fused" in a consistent manner with those obtained from the demand models to produce a base-line O-D matrix. This matrix is then modified by the demand models to reflect alternative external scenarios and ITS strategies. The resulting O-D matrices are used as inputs to the dynamic traffic assignment model.

The function of the dynamic traffic assignment model is to produce an "average" steady-state within-day dynamic distribution of trips. given initial time dependent O-D matrices. This module makes use of traveler behavior characteristics as well as dynamic network performance and ITS characteristics. This model revolves around a mesoscopic traffic simulator which is capable of representing both pre-trip and enroute traveler responses to ITS.

Dynamic Traffic Simulation. The dynamic traffic assignment model cannot capture stochastic factors of the transportation system and the operations of some ITS components at the necessary level of detail. This task can be accomplished by a microscopic traffic simulator. The simulator provides a detailed description or' ITS characteristics as well as the ability to model microscopic traveler behavior such as acceleration. lane changing and response to ATMS.

Two types of ATIS response models are included in the traffic models: (1)pre-trip ATIS usage and travel responses. and (2) en-route ATIS usage and travel responses. In the pre-trip model. travelers decide whether to use ATIS information before starting their trip and choose whether to comply (for prescriptive ATIS) or change their travel plan (descriptive ATIS). Adjustments can include canceling the trip, or changing destination mode, departure time, route or parking location. In the en-route model, travelers are classified based on their access to en-route ATIS. If traffic conditions are not as expected then they might decide to switch travel decisions just as in the pre-trip models.

Resource. The role of this set of models is to map the conditions observed in the dynamic traffic simulation to the performance measures required for policy evaluation. The measures of interest relate to air quality, energy consumption. level of service to travelers and safety. This mapping is achieved by either simple aggregation models or more complex simulation models, depending on the type of measure in question. For, example, in the case of travel time measures (reflecting one aspect of level of service), the model consists of a simple aggregation relationship based on individual travel times computed by the dynamic traffic simulator. On the other hand. in the case of carbon monoxide emissions measures (reflecting one aspect of air quality), a more elaborate model is required to translate acceleration and velocity data generated by the dynamic traffic simulator into emission levels.

ELEMENTS OF FRAMEWORK DEVELOPED AT MIT/CMU

At MIT/CMU we have been working on implementing an ITS evaluation framework over many years (Kaysi. 1992: Tarrech-Masdue 1993). Below we describe our accomplishments to date in the development of various models embodied in the framework shown in Figure 1.

Land Use

Research has been conducted at MIT in the past regarding the residential location choice (for example. Ben-Akiva. et al.. 1980: Weisbrod. Lerman and Ben-Akiva. 1980: Ben-Akiva and de Palma. 1986). Current research is extending this work to incorporate accessibility measures from the activity-based travel demand model system. and to establish a broader framework for modeling the urban development processes.

Demand

1. Activities and Travel. Ben-Akiva and Bowman (1995) developed an activity based discrete choice model system of an individual’s daily activity and travel schedule that can be used as the core demand model.

2. ATIS Awareness and Access. A behavioral framework of consumers’ market decisions. such as ATIS awareness and access decisions. has been developed by Ben-Akiva et al. (1993) Willingness to pay for ATIS has been investigated by Polydoropoulou and Ben-Akiva (1993). ATIS awareness and access models using data from the SmarTraveler traffic/transit telephone service are currently under development at MIT.

3. Telecommuting. MIT has developed and demonstrated a modeling framework to explain the telecommuting adoption process incorporating both the employer's and the employee's perspective (Bernardino and Ben-Akiva. 1995). The model allows the identification of the impact of telecommuting on the number of work trips.

Dynamic Traffic Assignment

We have conducted extensive effort to develop a comprehensive Dynamic Traffic Assignment Model (DTA) to support ATMS/ATIS applications. Specific elements include dynamic O-D matrix estimation and prediction (Ashok and Ben-Akiva, 1993; Cascetta et al., 1993), traffic simulation models such as MITTNS (Ben-Akiva et al.,1994), driver behavior models, etc. This effort is expected to continue with the FHWA/ORNL sponsored DTA project.

As part of our DTA effort, we have developed a mesoscopic traffic simulation model (MITTNS). MITTNS is a time-based simulator whose running time and accuracy can be controlled through aggregation of vehicles into units and appropriate choice of time step. There are two levels of vehicle aggregation. packets and cells. Packets are fixed in size for the entire simulation and consist of vehicles with uniform characteristics. Cells consists of packets and can change size and composition during the simulation. Traffic dynamics are captured through speed-density relationships (Ben-Akiva et al., 1994). We expect MITTNS to play an important role in operationalising the Dynamic Traffic Assignment Model.

Another research project we have been involved in is DYNA. funded by the Commission of the European Communities. The project is aimed at producing a real-time traffic prediction system for use in determining real-time motorway control strategies. As part of this research. two different models were developed: the Behavioral Traffic Model (or a DTA) with a longer prediction horizon and the Statistical Traffic Model with a shorter range outlook. The background gained from this research is particularly useful in developing an operational DTA. For more information see Ben-Akiva et al. (1995).

Dynamic Traffic Simulation

In addition to MITTNS we have also developed at MIT a ***microscopic*** traffic simulator (MITSIM - MIroscopics Traffic SIMulator) for detailed modeling of traffic network operations with advanced traffic control. route guidance and surveillance systems. MITSIM simulates individual vehicle movements using car following. lane changing and traffic signal response logic. A probabilistic route choice model is used to capture traveler route choice in the presence of ATIS. The simulator is part of a laboratory for evaluating traffic management systems and interacts with a surveillance module that can represent a wide range of sensors and a traffic management module that can represent a variety ot ATMS/ATIS.

MITSIM has at its core a set of microscopic driver behavior models. The two main models are for acceleration (including car-following) and lane-changing. Microscopic data is currently being collected to provide the necessary data-base for this research (for more Information see Ben-Akiva et. al., 1995: Yang and Koutsopouios. 1995: and Koutsopoulos et al. 1995).

Together. MITTNS and MITSIM provide us with a powerful set of tools for detailed representation and assessment of ITS and its associated benefits.

Traveler Behavior

A detailed description of the overall travel behavior framework in response to ATIS products and services is provided in Ben-Akiva et al. (1993).

ATIS usage models have been developed by Polydoropoulou et al. (1994), and Murashige (1995). These models explain the choice of information source, before starting the trip or while driving.

ATIS travel response models that can be used in our simulation have been developed by - Khattak et al. (1995) and Polydoropoulou et al. (1995). Conditioned by the acquisition of route guidance information from an ATIS, these models represent the decision to switch one of the pre-planned travel decisions such as destination, mode, departure time or route. Independent variables include the attributes of the alternatives and the attributes of the information provided.

Other ATMS/ATIS Research

Different approaches for predictive traffic control and routing have been developed at MIT as part of the Evaluation of the Real-Time Traffic Management System for Boston's Central Artery and Third Harbor Tunnel (CA/T) project (Ben-Akiva et al.. 1994). The main focus in the past 2 years has been on the development and short-term evaluation of ATMS alternatives.

Resource Model

The traffic models presented above (MITTNS and MITSIM) provide the inputs required by the resource models. The CA/T research mentioned above involves the short-term evaluation of ATMS alternatives. In this context. performance models are being developed for such an evaluation. Some of the measures relate to level of service to travelers. capacity utilization. emissions (Carbon Monoxide). and safety conditions. Some enhancements would be required for the assessment of medium- and long-term benefits as well.

CONCLUSION

In summary we would like to state that significant progress has been made by members of our research team on design. implementation. and validation of the individual modules of an ITS benefit assessment system as envisaged in the paper. The challenge therefore is to develop a computationally efficient system that integrates the models that we have developed as well as those developed elsewhere in a manner that ensures accuracy-and reliability. Further work is also required in translating performance measures obtained from this model system into an urban transportation planning and policy decision support system.

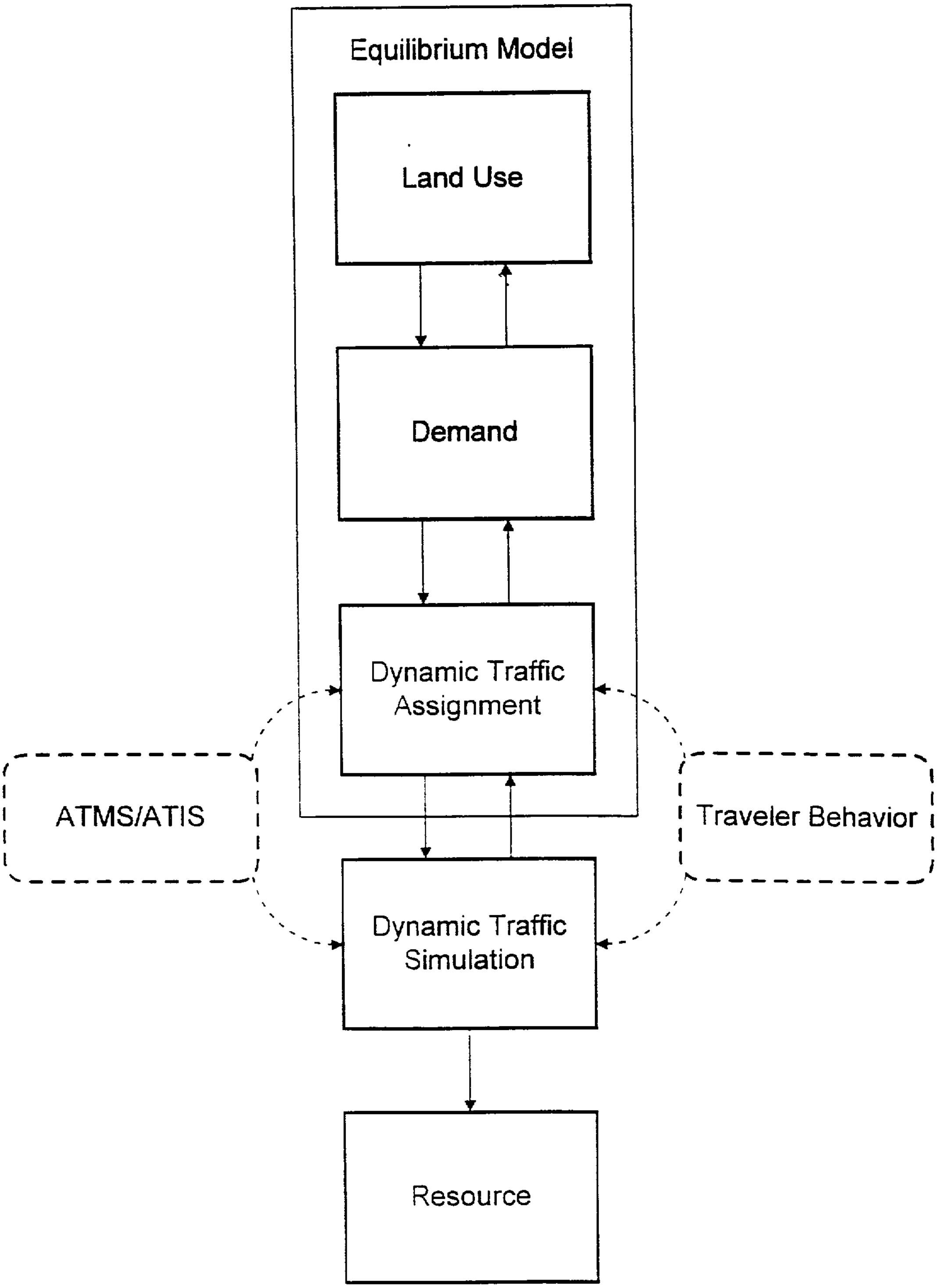

Figure 1: MIT/CMU Model Framework for ITS Benefits Assessment