Abridgment

A Decision Support System for Freight Transport in Arizona

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In this paper, the tasks and major findings of a freight transportation study conducted in Arizona are briefly described. The main goal of the study was to assess the freight movement performance of Arizona's highway network. A complete freight carrier modal directory, containing information on carriers that operate in the state, was developed. Freight movement surveys and attitudinal surveys were mailed to a sample of those carriers, and an information base about freight shipments on Arizona's primary and secondary highways was developed. A description of a decision support system, its structure, and components is provided, and discussions are presented of how this interactive computer-based system can be used by managers to apply both data and models effectively in decision making.

The study described in this paper was funded by and developed at the request of the Arizona Department of Transportation (ADOT). ADOT is concerned about the performance of the state highways and their ability to meet existing and future freight demands. Freight transportation is a relatively new focus, and currently ADOT does not have enough of the analytical tools and relevant freight data needed for comprehensive planning.

STUDY OBJECTIVES

The main goal of the study was to assess the freight movement performance of Arizona's highway network. The objectives were to develop tools to allow highway planners and decision makers to assess the effectiveness, efficiency, and economy of alternative highway policy decisions in serving the needs of Arizona citizens. The first objective of the study was to develop a freight carrier modal directory that would contain information on carriers that operate in the state, including company name, address, telephone number, carrier type (private, common, for hire), rank in terms of total mileage driven in the state, and account number with the ADOT Motor Vehicle Division (MVD). The second objective was to collect information on freight shipments on Arizona's primary and secondary highways. The third objective was to develop the Arizona Freight Network Analysis Decision Support System (AFNA DSS). This system was to have three major components:

- A preprocessor that converts the freight shipment data into a form that can be used by a simulation model,
- A model that simulates the movements of trucks on highway links between cities and collects statistics on system performance, and
- A planning module that allows "what if" analysis of the effects of freight movement on traffic congestion on highways, highway safety, and pavement maintenance.

The work for this study was divided into four modules (Figure 1):

- Modal freight directory,
- Freight movement information forecasting,
- Freight network analysis, and
- Management and strategic planning.

FREIGHT CARRIER MODAL DIRECTORY

Mail surveys addressed to freight carriers were selected as the most appropriate vehicle for data collection under the given budget constraints of the study. Two types of surveys were identified as necessary: freight flow surveys and attitudinal surveys. The surveys were designed by using statistical procedures to ensure reliable results (see the companion paper by Radwan et al. in this Record). A modal directory of freight carriers that serve the state of Arizona was found to be necessary to attain a successful sampling procedure.

A computerized data base management system (DBMS) was developed on a microcomputer to include the top 2,000 carriers (in terms of mileage covered on Arizona highways) of the 13,049 motor carriers registered in the state. The system was programmed with dBase III and contained information on the carriers' names, addresses, telephone numbers, MVD account numbers, type, and miles driven in Arizona. A statistical analysis of these 2,000 carriers made with the dBase III sorting utilities revealed that some 27.6 percent of these carriers are based in Arizona and that the top 200 carriers represent about 56 percent of the 983,237,200 mi driven by all 2,000 carriers.

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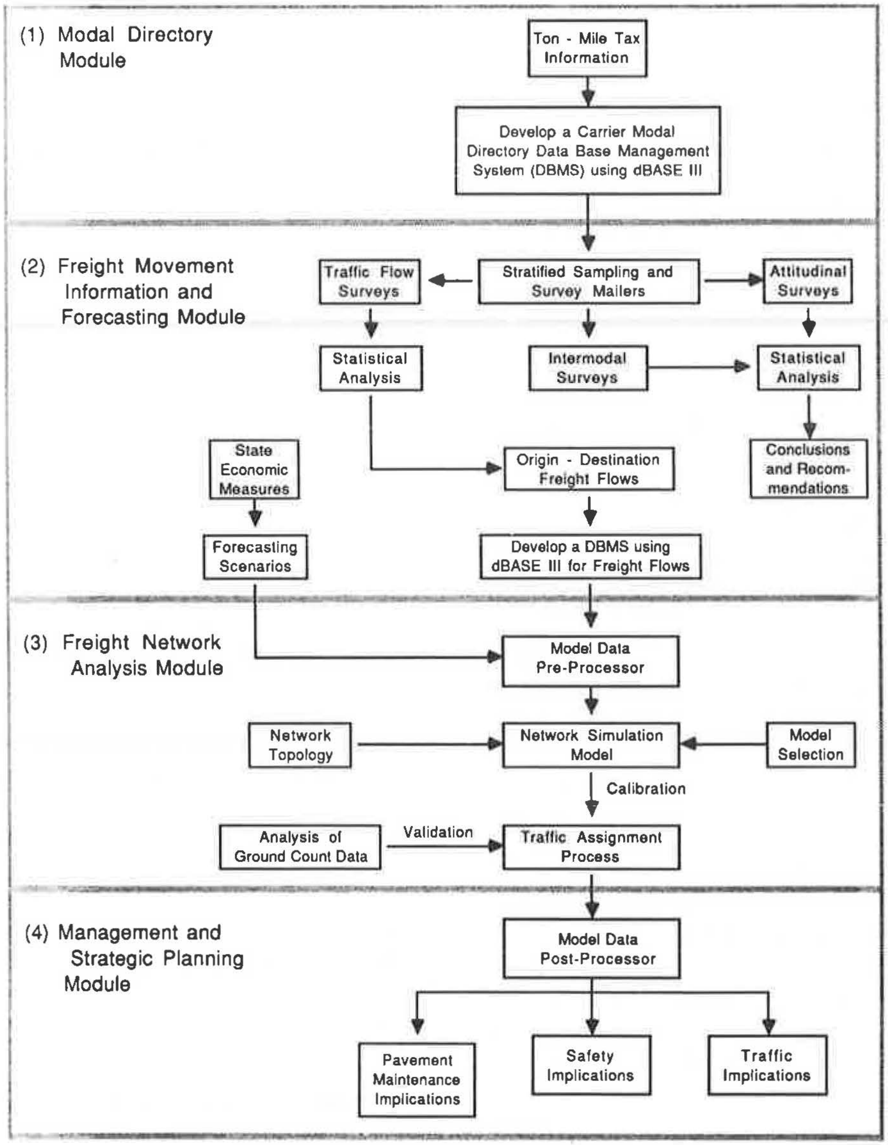


FIGURE 1 Research modules and tasks.

FREIGHT FLOW DATA

A stratified sampling technique was applied to the total population of carriers, and a sample size of 2,100 carriers was obtained. Three mailings of surveys were sent to these 2,100 carriers over a 6-month period. Follow-up telephone calls were made to the nonrespondents among the top 200 carriers.

Each mailing contained forms to be filled out and a self-addressed stamped envelope. The freight flow information requested on these forms was

- Name of contact person,
- Date,
- Carrier type (common, contract, or private),
- Shipping date,
- Commodity shipped,
- Gross weight,
- Shipment's origin (city, state),
- Shipment's destination (city, state),
- Routing through Arizona (highways used), and
- Comments.

Freight carriers that operate from intermodal facilities in Arizona (air terminals, pipeline outlets, and railroad facilities) also received mail surveys. In all, 254 carriers were surveyed, and the results are documented elsewhere (*1*) (see also companion paper by Radwan et al.).

AFNA DECISION SUPPORT SYSTEM

Today, managers are constantly challenged to make difficult decisions so that their companies may survive and succeed. Consequently, increasing numbers of managers are turning to decision support systems (DSSs) for aid in making these decisions. A DSS is an interactive computer-based system that allows managers to effectively use both data and models in decision making.

As mentioned before, the third objective of this project was to design and develop a DSS for freight movements, to be used by ADOT. The system incorporates the AFNA data base and a computer simulation model as its basis. The simulation model has been developed to simulate the movement of each truck on the highway and to collect statistics on traffic performance. A prime consideration in the development of the AFNA DSS was to create a program with all the best DSS characteristics: user friendliness, interactivity, and the capabilities of supplying various solutions from a model library and accessing relevant information from the data base. The AFNA DSS was designed to be used in freight movement planning to provide decision makers with information that is derived from the simulation model of the state highway network system. The data base and models that it contains will be used by the ADOT Transportation Planning Division to determine the statewide impacts of their decisions.

AFNA SYSTEM STRUCTURE

The general structure of the AFNA system and the flow of data files are depicted in Figure 2. There are five modules in the AFNA software environment: user-system interface, dBase III data base, model data preprocessor, SLAM II Arizona highway simulation model, and transportation planning.

The user-system interface module provides the control mechanism that allows the user to access the AFNA system. The menu-driven and question-answer on-screen dialogue provides the interface between user and system. In addition, the data base component (dBase III and data preprocessor) and the model base component (simulation and planning module) are linked by this same interface module, establishing the unification of the AFNA DSS architecture.

The dBase III data base module allows users the capability of retrieving data on freight carriers on the Arizona state highway network and flow, as desired. This module's primary function is the organization and preprocessing of the survey data on a trip-by-trip basis. The dBase III data base module has also been "taught" a portion of the route-link relations between key origins and destinations on the AFNA network so that a minimum of input work is required to handle the survey results as they arrive. The topological knowledge and raw survey data are combined to produce an output file, DB.OUT, that contains a summary of the date, carrier, weight, commodity, origin, destinations, and link information for each trip that was listed on a survey form.

The preprocessor module for the model data is designed to combine trips from common origins into an appropriate probability distribution on the basis of date, carrier code, weight, commodity code, and truck branching conditions. The resulting file, STD.DAT, is the driver for the AFNA simulation model. The STD file allows easy modifications to be made for conducting "what if" scenarios for many kinds of planning activities.

The Arizona highway simulation model processes the data file (STD.DAT) by creating entities (trucks) with appropriate attributes (commodity, weight) and controlling the flow of these entities through the AFNA network. The simulation model is used to conduct the experiments required for analyzing a planning scenario and provides a summary report for each run. By making simple changes to the input files (STD.DAT and NET.DAT), a planner can easily delete or upgrade links in the network being studied.

The transportation planning module uses the simulation output (SLAM.OUT) and combines it with other information, such as existing pavement conditions, base year cumulative loading, and accident statistics, to produce planning reports. These reports include such considerations as pavement maintenance and safety implications.

MANAGEMENT AND STRATEGIC PLANNING

Planning Functions Overview

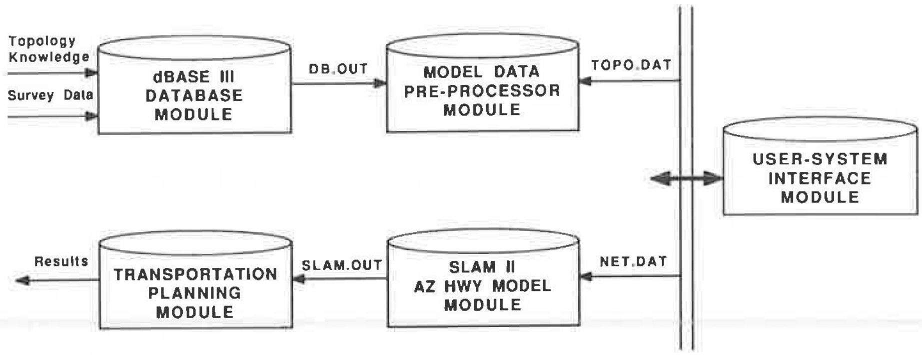
The AFNA simulation model is driven by survey data. This makes the static data become dynamic representations of truck flow on the Arizona freight highway network. This characteristic is a useful tool in planning tasks, especially the "what if" analyses.

If the user wants to run a simulation on a network of a different size than the provided STD file, all the changes need only be made in the data files because the simulation program has been designed as a generic model that does not contain any topology information. Even so, addition or subtraction of links may be performed on an individual basis, although the process may be tedious and time-consuming.

The user can apply various loading factors to the model to perform some forecasting functions. The total truck numbers in the current model are considered to be loaded with a global loading factor of 1.0. If the user predicts that in 1995 the total number of trucks will increase by 60 percent and assumes that the conditional branching probabilities remain the same, the user can apply a global loading factor of 1.60 to the current model, run the simulation, and study the results.

Safety Submodule

The function of the safety submodule is to compute annual estimates of the number and cost of traffic accident systemwide. The input data for this submodule include such variables as accident rates (accidents per million vehicle miles) for various types of highways and percentages of fatal accidents, injury accidents, and property damage only accidents. Current default values for these variables were obtained from the *Arizona Traffic Accident Summary* (*25*). The costs of accidents were estimated separately for each of the three categories (fatal, injury, property damage only) (*6*, pp. 120–121). The output of the safety module includes



FILE	DESCRIPTION
DB.OUT	Trip-by-trip record from survey data including O-D & link
STD.DAT	Aggregated node-based travel data
TOPO.DAT	Network topology, link and node relationships
NET.DAT	Network link data
SLAM.OUT	Simulation results for transportation planning

FIGURE 2 AFNA system and file structure.

- Input echo and comments,
- Table containing estimates of total number of accidents by severity class for each link,
- Table containing estimates of total accident costs by severity class for each link,
- Table containing the maximum, average, and minimum accident costs during the plan period for each link, and
- Accident cost summary for the whole system, given as totals for the entire network.

Pavement Maintenance Submodule

The pavement maintenance submodule is used to provide cost information for selected maintenance options. The maintenance options that can be selected for analysis are pavement replacement, pavement rehabilitation (resurfacing), and regular annual corrective and preventative pavement maintenance.

After the user inputs the cost data, the machine prompts for inputting the code numbers of the links that contain segments that are to be considered for a given maintenance plan. A maintenance plan is considered to be a combination of maintenance options whereby a set of highway segments that is scheduled for maintenance is broken down into subsets that are assigned to various maintenance options. So that a record of the locations of the various segments can be kept, the user is expected to input arbitrary reference code numbers (as integers) for all segments. Although the segment numbers are arbitrary, the code numbers for the links (mentioned previously) refer specifically to the link numbers assigned to the links in the standard network topological system.

To make the input procedure for this submodule easier, the user should decide in advance which subsets of segments are to be assigned to pavement replacement or pavement rehabilitation and which will be assigned to regular maintenance only. The length of the segments must also be determined. An interactive input routine is provided for input of a set of mixed data subsets: segment list for replacement, segment list for pavement rehabilitation, and segment list for regular maintenance.

The output of this submodule is in four parts:

- List of all links and segments subject to pavement replacement and the costs associated with the action,
- List of all links and segments subject to pavement rehabilitation and the costs associated with the action,
- List of links subject to regular maintenance, and
- Cost summary for the entire maintenance plan.

The numerical output of this submodule is used to give the planner-user cost estimates that can be quoted when maintenance plans are being analyzed.

STUDY FINDINGS

The DSS proved to be a useful framework for this study (7). The modular software integration approach incorporated the separate programs developed by the AFNA project team into a unified package. A main-line dialogue-generation and control program was the keystone of the integration because it serves as a common interface among the system modules and the AFNA user.

To execute a large-scale transportation simulation model, a communication network between microcomputer and mainframes is needed. The AFNA simulation model runs on a mainframe, but the model data preparation, output analysis, and presentation are done on a personal computer to take advantage of that machine's excellent user interface.

The model developed for the AFNA system is data driven. The data-driven modeling approach is different from the traditional approach to simulation modeling, which combines data, knowledge, and control in its programming. The data-driven approach treats the data and control logic as distinct parts. The resulting model can thus be used in many different applications, without modifying the actual program (*8*).

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