NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT 177

FREIGHT DATA REQUIREMENTS FOR STATEWIDE TRANSPORTATION SYSTEMS PLANNING

RESEARCH REPORT

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
REPORT 177

FREIGHT DATA REQUIREMENTS FOR STATEWIDE TRANSPORTATION SYSTEMS PLANNING

RESEARCH REPORT

ROGER CREIGHTON ASSOCIATES, INC.
DELMAR, NEW YORK
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R. L. BANKS & ASSOCIATES, INC.
WASHINGTON, D. C.

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:

- TRANSPORTATION ADMINISTRATION
- TRAFFIC MEASUREMENTS
- URBAN TRANSPORTATION SYSTEMS
- RAIL TRANSPORT
- AIR TRANSPORT
- WATER TRANSPORT

TRANSPORTATION RESEARCH BOARD
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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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FOREWORD

By Staff
Transportation
Research Board

State and regional planners concerned with freight transportation will find this report to be of special interest. Lack of basic data has been a significant deterrent to comprehensive analyses in the freight planning activities of all transportation modes. Also, because freight planning is a relatively new function for many states, future data requirements are not well known. This report provides a detailed assessment of existing freight issues and identifies the data required to apply the related analysis techniques. A companion document, *NCHRP Report 178,* contains a User's Manual presenting a detailed catalog of existing data sources, methods to obtain missing data, and guidelines for data collection and management activities in state agencies. Use of these two NCHRP reports should facilitate the development of data collection programs and, hopefully, minimize the collection of unnecessary data.

The need for research in this area was determined at the TRB Conference on Statewide Transportation Planning, February 21-24, 1974; the conference findings are reported in *TRB Special Report 146.* Data collection activities typically involve high costs and large commitments of staff, as clearly evidenced in state highway traffic counting programs and urban origin-destination surveys. Relating the scale and make-up of a data collection program to the actual needs of the "user" has often been a trial-and-error process resulting in either excessive collection costs or unmet data needs, or both. In the infancy of freight planning by state agencies, this project was initiated in an attempt to disseminate information that would assist planners in their data collection efforts and to ease the trial-and-error process.

Because freight planning techniques are in the early developmental stages, supporting data requirements will undoubtedly change over time. This point was fully recognized at the initiation of this research; however, because techniques and data are so intertwined, and because the development of new and revised techniques is a never-ending process, an early assessment and documentation of data types, characteristics, and sources was desirable. *NCHRP Reports 177* and *178* should serve as a basic reference during the development of improved analysis techniques through future research and planning activities.

NCHRP Report 177 presents an assessment of freight data requirements, data availability, and unmet data needs in relation to current problems and issues. The information is presented by mode for various planning stages (i.e., initial, intermediate, and advanced), by data category (e.g., traffic flow), and by planning activity (e.g., economic evaluation). Strategies to develop data collection activities are also outlined. Although this research focused on data needs, a useful state-of-

the-art summary of techniques for (1) demand estimation, (2) modal choice modeling, (3) network analysis, (4) economic evaluation, and (5) impact estimation are included in appendixes. The User's Manual, *NCHRP Report 178,* presents guidance for identifying data requirements, obtaining primary and secondary data, and data management. Of special value is the extensive catalog of existing freight data sources contained in an appendix to the User's Manual. Both reports cover highway, rail, water, air, and pipeline modes of transportation.

This research was conducted by Roger Creighton Associates of Delmar, N.Y., and R. L. Banks & Associates of Washington, D.C. Their direct contacts with federal and state agencies during the conduct of this research and their familiarity with other efforts in this general area serve to make the findings contained herein directly relevant to current issues. For example, these research findings should be useful in conjunction with the *Rail Planning Manual* published by the Federal Railroad Administration.

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Frederick W. Memmott, Senior Associate, Roger Creighton Associates Incorporated, was the principal investigator and Richard B. Blackwell, Vice-President, R. L. Banks & Associates, Inc., was the principal investigator for that firm. The other authors of the report are: Roger L. Creighton, President; Charles W. Manning, Associate Transportation Planner; Leslie E. Sterman, Senior Transportation Planner; and Frederick S. Scholz, Senior Transportation Planner, of Roger Creighton Associates Incorporated, and Nai-Chi Wang, Senior Statistical Associate; W. Gifford Moore, Chief of Railroad Planning; Charles E. Shaw, Senior Transportation Analyst; and Cline D. Barton, Transportation Analyst, of R. L. Banks & Associates, Inc.

The assistance of state planning personnel in California, Connecticut, Iowa, Maryland, and Wisconsin is gratefully acknowledged.

FREIGHT DATA REQUIREMENTS FOR STATEWIDE TRANSPORTATION SYSTEMS PLANNING
RESEARCH REPORT

SUMMARY

Urgent matters (such as railroad bankruptcies, energy and environmental problems, and land settlement issues) impel state and federal governments to increase planning activity in the field of freight transportation planning. Because freight transportation is a relatively new focus, state departments of transportation are often not familiar with the kinds of freight data needed for such planning. Little is known about currently available data, their reliability, their compatibility among different sources, their temporal continuity, their units of aggregation, and their costs. Knowledge of data sources is indispensible to sound planning.

Accordingly, the research problem was to identify and rank data essential to freight transportation planning and to begin building a core of knowledge about these data that will be useful to those engaged in such planning at the state level. The findings of this research are presented in this report, *NCHRP Report 177,* "Freight Data Requirements for Statewide Transportation Systems Planning—Research Report," and a companion report, *NCHRP Report 178,* "Freight Data Requirements for Statewide Transportation Systems Planning—User's Manual."

The research approach consisted of:

- Identifying the principal problems/issues facing states through state visits and information from other sources.
- Through examining problems/issues, deducing the types of state-level planning activities needed to deal with these problems/issues and their corresponding data requirements.
- Through contacts and a literature review, identifying available planning methods and their individual data requirements.
- Cataloging available secondary data sets.
- Assessing unmet data needs by comparing data requirements with the data supply, both quantitatively and qualitatively.
- Assessing the criticality of unmet data needs and proposing alternative strategies to improve the data supply through both state- and federal-level activities.

A pervasive factor in the research work—and a major finding of the project—is the immature state of the art of freight transportation planning. There is a great diversity of problems and issues, of possible state roles in freight planning, and geographic/jurisdictional levels at which problems occur. There is, as a result, a diversity of actual and potential planning responses. The research team found no consensus as to a formalized process by which different planning activities could be woven together to produce a plan, or, in fact, any agreement as to the content of a freight plan.

The research team found, through examining 74 major freight problems/issues:

- The greatest data need was for physical and operating data, especially information on facility location, operation characteristics, use, and capacity. This

occurs regardless of mode and priority group. This data need is especially important during the beginning phases of freight planning.

- There is a strong need for information on vehicle flow and on plant condition and unit costs, both capital and operating.
- Data supporting impact estimation are of moderate importance, especially data relating transportation system change to public health and safety. Of lesser importance is detailed information on the carriers themselves and the attributes of shippers and receivers.

Four kinds of planning activities were examined in detail: demand forecasting, modal choice analysis, economic evaluation, and impact estimation. The examination was for three main purposes: (1) to identify the likely planning activities by stage, (2) to determine data requirements, and (3) to assess the current state of the art. Each of the four activities was found to have a sizable number of technical methods or models within it, some fairly standard or well-perfected, others largely untested or experimental. Key findings from the examination of planning methods include:

- *Demand forecasting.* The interdependency of freight or commodity flow and macroeconomic data in forecasting—that freight demand forecasts can be no better than estimates of total economic growth and change. Trend extensions and simple correlations of traffic flow data with macroeconomic variables, which represent the current state of the art, must ultimately be replaced by more advanced techniques that take into account economic interdependencies, differential regional growth and specialization, and technological change.
- *Mode choice analyses.* The interdependency of data and theory, the lack of consensus among professionals on both data and theory, and the fact that, even were agreement reached, much developmental work remains to be done before mode choice models can be readily applied by state planners to freight statewide transportation systems planning. Model development has been hampered by the scarcity of suitable traffic flow data containing transport level-of-service and commodity attributes.
- *Network analysis.* Mechanical assignment methods must be developed further to simulate more realistic routings of freight traffic. The development of these more refined methods is directly related to improvements in traffic flow data availability.
- *Economic evaluation.* Methods for developing cost, rate, transport time, and time reliability information must be further developed to support economic evaluation activities. Cost and rate data are so specialized, difficult to understand, and changeable over time as to effectively preclude direct state involvement with original data sets.
- *Impact estimation.* Techniques for impact estimation, although originally developed primarily for application at the project level, can be adapted to use in systems planning to the extent that supporting traffic, operating, and physical data are available, as well as information on ambient conditions necessary to determine air, noise, and water pollution impacts. More refined estimates of unit energy consumption and emissions productions are also needed to more closely simulate actual conditions.

With respect to data availability, substantial resources were found to exist that can be used for freight statewide transportation systems planning. These data are not all in the form or in the degree of detail needed for planning purposes,

nor are the various data files consistent as to type or degree of geographic detail so as to make them easy to use. The research team found 80 principal data sources, 114 other sources, and 34 reference sources. These have all been catalogued in an appendix of *NCHRP Report 178,* "Freight Data Requirements for Statewide Transportation Systems Planning—User's Manual," a companion volume to this one.

The purpose of the catalog is to aid the state planner in locating and obtaining suitable data as required for freight planning. Given the extensiveness of the data sources listed and the need for priorities, recommendations have been included as to which data sources states should acquire, referenced by planning stage, mode, and order of acquisition.

For each of 31 freight data categories, assessments were made of present availability and quality. These were compared with the frequency that the particular data categories are required in statewide transportation systems planning to determine the criticality of deficiencies and unmet data needs. The most important unmet data needs were found to be:

- Commodity flow and traffic flow data.
- Routing data.
- Rates/tariffs data.
- Transport level-of-service data.
- Unit cost data (capital and operating).

Strategies to reduce deficiencies and generally to improve the quality of data available to the states differ as a function of the data category and the criticality of the deficiency. Five basic strategies for improving the quality and quantity of available data were identified and discussed in detail. These include: (1) assembling similar data sets, (2) publishing and disseminating data, (3) establishing close working relationships with carriers, (4) expanding the sample rates of federal data sets, and (5) expanding the *Census of Transportation.* For certain types of physical and operating data, states can best assemble the required data. Given the administrative and technical difficulties involved and the relatively high cost of new surveys, states are not advised to conduct their own primary surveys except in cases (such as a shipper's survey) where limited, specialized information is required that is not available from any other source. States should basically rely on existing secondary data for freight transportation systems planning purposes.

CHAPTER ONE

INTRODUCTION AND RESEARCH APPROACH

RESEARCH PROBLEM STATEMENT

Many state DOT's, as well as other state and regional agencies, are now concerned with preparing or assisting in the preparation of statewide "master plans" for motor carrier, rail, air cargo, pipeline, and water facilities and services to meet existing and future freight demands. Some state DOT's are actively working on various components of the freight transportation system, through (1) responding to immediate problems or issues, (2) conducting project or program studies having a specific modal or facility-type orientation, and (3) reassessing state policies toward infrastructure investment, required services, costs, and competition.

These are relatively new activities for many state DOT's; in the past their concerns have focused primarily on highway transportation and particularly on planning for capital facilities. State and Federal laws have for the most part been related to regulatory matters and safety. The actual business of moving freight has been the responsibility of private companies, and these competed not only within modes but also between modes.

Now, however, a variety of urgent matters impels state and Federal governments to increase activity in the field of freight transportation. The bankruptcy of several major eastern railroads has caused the Federal government to reorganize these lines and to provide funds for rehabilitation of their physical facilities. High energy prices and shortages indicate a need to look at all modes to see where savings can be made. The environment continues to be a major issue. Finally, there is a need to provide, wherever possible, a more coordinated freight transportation system and to relate that system better to land settlement patterns.

Because freight transportation is a relatively new focus, state DOT's are often not familiar with the kinds of freight data needed for such planning. Little is known about currently available data, their reliability, their compatibility among different sources, their temporal continuity, their units of aggregation, and their costs. Knowledge of data sources is indispensible to sound planning.

Accordingly, the research problem is to identify and rank data essential to freight transportation planning and to begin building a core of knowledge about these data that will be useful to those engaged in such planning at the state level. Methods by which such data can be assembled are also described.

RESEARCH OBJECTIVES

The general objective of this research was, first, to determine the type, amount, and relative importance of freight data required to develop statewide transportation systems plans; and, second, to design and develop techniques, methods, and procedures for assembling these data.

The specific objectives of the research were:

1. Identify the types of freight data necessary for statewide transportation systems planning purposes. Recommend what type of data and the scale of detail required in view of the current and proposed planning methodologies.
2. Rank these data requirements in terms of their relative importance to statewide transportation systems planning.
3. Given the data requirements, catalogue and determine the existence of available data in reference to the planning data requirements determined in Task 1. This inventory of freight data was to pay special attention, but not be limited to: (a) a review of selected statewide "master plans," (b) a review of studies performed and data collected for the 1972 and 1974 National Transportation Studies, and (c) a review of freight data compiled by government sources and organizations such as national and local trade and carrier associations. Investigate the institutional problems and constraints in the use of freight data (e.g., disclosure restrictions, proprietary nature of shipper and carrier data, and joint use and reciprocity agreements among private and public parties).
4. Identify deficiencies in existing freight data and evaluate the criticality of such deficiencies to statewide transportation systems planning.
5. Develop and evaluate alternative strategies for resolving such deficiencies. These strategies may range from creative use of existing data to extensive collection of primary data.
6. Prepare a manual describing in detail appropriate techniques for the assembly and understanding of existing freight data and the collection and understanding of such additional data as may be required by statewide transportation systems planning. Such a manual was to include specification of data acquisition, processing, verification, and maintenance procedures.
7. Provide illustrative, realistic examples of how to apply these techniques to typical problems encountered in statewide transportation systems planning.

SCOPE

The term "systems planning" as used in this research project was interpreted broadly to include policy, systems, regional, corridor, and modal or submodal (e.g., branch line, main line, or route) planning. It was felt that state-level freight transportation system planning would simultaneously encompass all of these levels or types of planning, and that the main emphasis of this research must be on defining the data needed to support all such planning activities. In urban transportation planning, systems planning

refers to the complex but orderly process in which plans for entire networks are devised and tested or evaluated by computer traffic assignment. This capability is only partly operational in freight transportation, and full operational capability is not expected in the near future.

It is virtually impossible to reach universal agreement on what constitutes statewide freight planning. Each state would interpret it differently. Some states see a strong interdependency with national or multi-state planning. Others largely limit state DOT activities to defined or legislated responsibilities. Still other states are concerned mainly with regional or localized problems within the state. Modal emphasis varies, depending on the presence or absence of different modes, legislated authority, and the importance of the freight-related problems or issues facing the state. In the end, each state must decide for itself what it considers freight statewide transportation systems planning to be.

Planning for urban goods movement was considered to be a separate field, with its own data requirements. Likewise, project-level or subarea planning (if not carried out uniformly across the state) was considered to be outside the scope of this research project. State response to freight "problems and issues" was included primarily because most state freight planning activities are oriented to problems and issues rather than to the urban "systems" approach developed in response to the 1962 Federal-Aid Highway Act.

RESEARCH APPROACH

The following steps constitute the research approach:

1. *Issue identification.* The consultant visited five states and by a combination of structured and unstructured interviews identified the principal problems and issues facing states in the field of freight transportation. Information on freight planning methods and on data was also collected.

2. *Identification of planning methods.* Available planning methods, many of them at the frontiers of the state-of-the-art, were identified through contacts with public agencies, private companies, and universities, and through an extensive literature review.

3. *Data needs identified from issues and planning activities.* By examining the diverse problems/issues facing state DOT's, it was possible to deduce the types of planning activities necessary to deal with these problems/issues, and then to determine the data requirements of the planning activities. This approach permitted data needs to be prioritized, inasmuch as the interviews had indicated the relative importance of the various issues.

4. *Data needs of planning methodologies.* By studying in detail selected planning methods for demand estimation, modal choice analysis, network analysis, economic evaluation, and impact estimation, it was possible to determine their individual data requirements. Data needs could then be generalized for each of the five areas.

5. *Catalogue data.* Lists of available data sets were obtained from all known sources collecting freight data. Principal data sets were catalogued, giving information on the source of the data, sampling rates (if any), the contents of data files, significant exclusions, future update or extension plans, data availability, constraints on dissemination, workmanship, and available summaries. In addition, an evaluation was made of the usefulness of principal data sets in freight statewide transportation systems planning. This is intended to facilitate the work of the state planner in conducting freight-related studies. Abbreviated information was catalogued for other data sets and references.

6. *Strategy to improve data supply.* By comparing data requirements (identified by two separate procedures), with available data, unmet data needs were determined. Strategies were then proposed to correct and improve data supply, both short- and long-term.

GUIDE TO DOCUMENTATION

The research results are presented in this report and a companion "User's Manual" (*NCHRP Report 178*), as follows:

Research Report

The report presents research findings, interpretations, and conclusions. The body of the report is for a general audience—particularly those responsible for managing or supervising over-all statewide freight transportation systems planning. It presents the data needed for freight planning in summary form. The appendixes present detailed information required by technicians and others practicing in the field.

Chapter One, "Introduction and Research Approach," briefly summarizes the problem that led to the research (the need to identify and rank data for freight systems planning purposes), the defined objectives and scope, and the specific approach used in undertaking the research work.

Chapter Two, "Findings," presents the research results, including over-all freight data needs, data availability, data deficiencies, and alternative strategies and recommendations for resolving unmet data needs.

Chapter Three, "Interpretation, Appraisal, Applications," discusses the findings in the light of the current state of the art at the state level.

Chapter Four, "Conclusions and Suggested Research," presents the recommended strategies for improving freight data which should be carried out at the federal and state levels.

Appendixes A through H present (for a technical audience) the research done in identifying freight data needs. Appendix A identifies freight data requirements derived through the systematic examination of freight issues or problems. The method given can be used by states to derive their own unique needs based on the characteristics of the transportation system and resulting problems and issues within that state. Appendixes B, C, D, E, and F identify data needs derived through an examination of available planning methods for demand estimation, modal choice analysis, network analysis, economic evaluation, and impact estimation. Appendix G assesses the data needs identified in the earlier appendixes in the light of the data that are available, thus deriving unmet data needs. This appendix further proposes and assesses different strategies

for resolving these unmet needs. Appendix H is a bibliography, organized by seven categories, of published materials having value in freight planning work.

User's Manual

The User's Manual (*NCHRP Report 178*) is a long-term reference for identifying and locating primary and secondary freight data sources. It is organized to enable the user to locate data resources either for a specific problem or to establish and maintain, at the state level, a freight data acquisition program. The manual includes illustrative examples showing how primary and secondary data needs may be determined and the data actually assembled.

Appendixes A and B of the manual provide examples of data collection methods, shipper surveys, and physical inventories. Appendix C catalogs 228 existing secondary sources of freight data.

CHAPTER TWO

FINDINGS

A pervasive factor in the research work—and a finding of the project—is the immature and fragmented state of the art of freight transportation systems planning. There is a great diversity of problems and issues, of possible state roles in freight planning, and geographic/jurisdictional levels at which problems occur. There is, as a result, a diversity of actual and potential planning responses. The research team found no consensus as to a formalized process by which different planning activities could be woven together to produce a plan, nor, in fact, any agreement as to the content of a freight plan.

This situation results from a number of factors. One is the newness of the field, but this is primarily a symptom of a more fundamental cause: the divided responsibility for freight planning, not only between governments, but also between government and private enterprise. There still remains a great deal of uncertainty as to the proper role for state government in this field. Lack of data has not been helpful to planners, either public or private, and this is in part the cause of the immaturity of technical processes.

Freight planning stands in sharp contrast to urban transportation planning. By and large, in urban transportation planning there is only one client (government), one commodity (people), and two modes (auto and mass transportation). There is a mature process that integrates many separate planning activities toward a plan. The content of the plan tends to expand slowly (e.g., by adding "transportation systems management" (TSM) elements) but there is consensus about its contents. None of this is true for state freight transportation planning.

Two consequences flowed from this situation that affected the research design.

First, the research work had to cover a very large span of issues and planning activities—and their data requirements. Presenting the kinds of planning activities likely to be undertaken became an important activity of the research work, inasmuch as many techniques are not well known to state planners. The six modes (rail, motor carrier, port, waterway, air, and pipeline) all had to be addressed. Consequently, it was not possible to be rigidly precise about the exact requirements of the contents of a particular file of data, or sample rates at which it should be collected, or the sensitivity of the process to the quality and sample size of data. A research policy of identifying all inclusive data requirements was demanded, but it was not possible to establish specific file parameters.

Second, the research work had to be structured to permit individual states to use the results to identify and prioritize their individual statewide freight planning programs and data collection activities. This research policy responded to the wide variety of problems/issues facing states and to the expected variety of roles that states may adopt. What is reported here regarding needs and priorities is an amalgam of the experience of five states (Connecticut, California, Iowa, Maryland, Wisconsin) that have done more statewide freight planning than most of the others. Consequently, throughout the appendixes detail is provided which will permit states to reduce data needs from planning methods that respond to their particular needs.

FREIGHT DATA REQUIREMENTS

Appreciable effort was devoted to (1) identifying freight problems or issues likely to occur at the state level, (2) identifying freight planning methodologies and their data requirements, and (3) ranking and classifying data requirements. Two approaches were used to identify the most important and essential data. The first was a "top-down" approach of first identifying important issues and problems, then deriving (1) the level or scope of the problem, (2) the state role in addressing the problem, (3) the major planning activities that would logically be carried out at the state level, and (4) the major classes of data that would be needed to undertake transportation systems planning. This work is discussed in Appendix A. The second, or "bottom-up" approach, required a careful and detailed

study of the literally hundreds of different analytical procedures that have been applied in the study of freight transportation. The ultimate objective was not to weigh the pros and cons of different procedures but rather to identify the types of data required, especially the level of detail and other characteristics. This work, which is discussed in Appendixes B through F, covers (1) demand estimation, (2) modal split, (3) network analysis, (4) economic evaluation, and (5) impact estimation.

Problems and Issues

This section reports on the analysis of the 74 freight transportation issues and problems identified in the "top-down" analysis. Examples of the types of problems and issues covered include: (a) condition of roadbed and track structure on railroad main lines; (b) merger of competing or complementary railroads; (c) temporal restrictions on highway use by motor carriers; (d) poor highway access to ports for intermodal service; (e) air cargo terminal replacement, modernization, expansion; and (f) slurry pipelines.

Type of Problem/Issue

The 74 problems/issues have been classified into the six types given in Table 1. A problem/issue may fall into one or more types. Consequently, there is a total of 140 indicators in the table. Based on the number of indicators, "line-haul" problems/issues are the most important, but "infrastructure" and "impact" have nearly as many. Indicators of "intermodal," "terminal," and "competitive" problems/issues are about half as frequent, but are still significant. From this table it is concluded that most states will have to deal with all of these categories of problems/issues.

A second total line in this table shows the number of problems/issues for each mode. In this summary each is assigned to only one mode; then the total is 74.

Level or Scale of Problem/Issue

For this classification, given in Table 2, problems/issues have been grouped based on their primary geographic impact area. Again, a single problem/issue can occur at one or more levels (for example, "terminating services on light-density lines" can have both a substate or regional and a local impact. The frequency of indicator occurrence is high for both state-level and local problems/issues. The national level is a close second. But a significant number of problems/issues occur at the multistate regional and substate regional levels. It may be concluded that problems occur at all levels, and that state DOT's will have to think beyond their borders as well as within.

State DOT Role. The roles which states must play relative to the various problems/issues are quite diverse as shown in Table 3. Undertaking technical studies is the most frequent role that must be played; but states must also support (or work with) other governments, promote (en-

TABLE 1

INDICATORS OF THE FREQUENCY OF PROBLEMS/ISSUES BY TYPE, BY MODE

TYPE OF ISSUE OR PROBLEM	RAIL	MOTOR CARRIER	PORT	INLAND WATER-WAY	AIR CARGO	PIPE-LINE	TOTAL
Intermodal	5	2	4	0	1	1	13
Line haul	13	9	1	7	1	3	34
Terminal	3	3	4	0	3	2	15
Competition	7	2	2	1	2	2	16
Infrastructure	10	6	7	5	2	1	31
Impacts	5	6	6	6	5	3	31
All indicators	43	28	24	19	14	12	140
All issues	25	16	12	9	8	4	74

TABLE 2

INDICATORS OF THE FREQUENCY OF PROBLEMS/ISSUES BY LEVEL OR SCALE, BY MODE

LEVEL OR SCALE OF ISSUE OR PROBLEM	RAIL	MOTOR CARRIER	PORT	INLAND WATER-WAY	AIR CARGO	PIPE-LINE	TOTAL
National	5	6	5	6	3	2	27
Multistate	8	1	2	2	1	1	15
State level	12	12	3	3	1	3	34
Substate or regional	9	3	2	1	0	2	17
Localized	13	7	8	3	3	0	34
All	47	29	20	15	8	8	127

TABLE 3

INDICATORS OF THE FREQUENCY OF PROBLEMS/ISSUES BY STATE DOT ROLE, BY MODE

STATE DOT ROLE	RAIL	MOTOR CARRIER	PORT	INLAND WATER-WAY	AIR CARGO	PIPE-LINE	TOTAL
Supportive	3	5	5	5	3	2	23
Technical study	12	8	7	4	3	1	35
Promotional	12	7	4	1	3	0	27
Coordinative	8	3	4	1	1	3	20
Capital investment	10	3	3	0	0	0	16
Other financial	1	0	0	0	0	0	1
All	46	26	23	11	10	6	122

courage) changes on the part of private carriers, coodinate, and make capital investments. These roles vary widely by mode. The diversity of state roles has an obvious influence on the kind of planning activities they will undertake.

Types of Planning Activities

Seven types of state-level planning were defined as useful in implementing the various state roles. These varied from "acquire background information and understanding" to "impact estimation" (see Table 4). Identifying the indicators was a subjective task because only a few of the problems/issues have been addressed by state or federal studies. The sum of each of the seven types of planning activities for a given mode may be considered to be "system planning." The sum of the types of activities for all modes may be considered to be "comprehensive freight transportation planning."

Priorities

States will vary in the priorities that each assigns to each of the 74 problems/issues that were identified. The priorities given in Table 5 represent those for a representative state (based on interviews in the five selected states). In this case, rail has the greatest number of problems/issues, followed in descending order by motor carrier, port, inland waterway, air cargo, and pipeline. Of the 74 issues, 11 are considered to be of high priority and these fall entirely in the rail and motor carrier modes.

Data Needs Through a Problems/Issues Approach

The value of the problems/issues approach to identifying freight data needs lies both in the results obtained and reported herein and in the fact that the process can be applied by individual states to assess their own unique data needs. States can follow a general process similar to that described in the User's Manual (*NCHRP Report 178*) using staff and advisory committee judgment to determine which issues are important, and can then program their planning activities and identify the data sets that are needed. The listing of problems/issues can be subdivided or expanded, if so desired, to account for local conditions.

Data needs identified in this project are presented by three priority groups. The "priority group" was principally determined by the importance of criticality of the problems/issues facing states, as reported in Appendix A (Tables A-7 through A-12). The three priority groups are defined as follows:

TABLE 4

FREQUENCY OF FREIGHT PLANNING ACTIVITIES, BY MODE

MODE	BACKGROUND INFORMATION	SHORT-RANGE FORECASTING	LONG-RANGE FORECASTING	MODE SPLIT	NETWORK ANALYSIS	ECONOMIC EVALUATION	IMPACT ESTIMATION
Rail	M	M	L	L	M	H	H
Motor carrier	M	M	L	M	M	H	M
Ports	M	M	L	L	M	H	H
Inland waterway	M	H	M	M	M	H	H
Air cargo	M	H	L	L	H	H	M
Pipeline	M	M	L	L	M	H	H
All	M	M	L	M	M	H	H

H = high frequency (> 14 weighted activities); M = medium frequency (8.0-13.9 weighted activities); L = low frequency (< 8.0 weighted activities).

Priority I. The issue or problem has been of high public interest in at least a dozen states during the past several years. There is a high probability of state transportation agency involvement, even by those agencies just starting out in freight planning.

Priority II. The issue or problem is of appreciable concern and interest in one or more states, as demonstrated through staff study efforts. There is a moderate probability of short-range state transportation agency involvement, especially by the more experienced agencies.

Priority III. The issue or problem has not yet reached the point of serious study by any state transportation agency staff, although there is expressed interest. There is some likelihood of future state transportation agency involvement, especially by the more experienced agencies.

The data needs identified through the problems/issues approach are summarized in Figure 1, which shows the relative frequency of each data need by priority category. Priority I data needs center on the rail and motor carrier modes, Priority II on these modes plus ports and inland waterways, and Priority III on all six identified modes (see Table A-14). From Figure 1, the following findings were drawn:

1. Priority I data needs:
   (a) The greatest data need is for physical and operating data, especially information on facility location, operation characteristics, use, and capacity. This occurs regardless of mode and priority group. This data need is especially important during the beginning phases of freight planning.
   (b) There is a strong need for information on vehicle flow, plant condition, and both capital and operating unit costs.
   (c) Data supporting impact estimation are of moderate importance, especially data relating transportation system change to public health and safety. Of lesser importance is detailed information on the carriers themselves and the attributes of shippers and receivers.

2. Priority II and III data needs. As freight planning becomes more sophisticated (i.e., states become involved with priority group II and III issues), data needs change from a heavy concentration on physically based data to a broader, more comprehensive range of data. The needs for traffic flow, carrier, and shipper/consignee attribute data increase, whereas the requirements for physical, operating, and impact data decrease. This same pattern is generally true across the modes. Specific observations are as follows:

   (a) Initial data requirements for traffic flow data largely center around vehicle flow data. Priority II problems/issues indicate a strong need for traffic flow and routing data in addition to vehicle flow data. Priority III requirements show a moderate need for commodity production and consumption, and commodity flow data, as well as specialized information on imports and exports. Over-all, there is a trend toward increasing amounts and diversification in traffic flow data.
   (b) Priority III requirements indicate some need for carrier data, including information on rates and tariffs. Otherwise, requirements for data on carriers appear to be fairly modest.
   (c) Data requirements for shipper/consignee attributes under all priority groups are modest, reflecting the rather narrow, pragmatic, problem-solving orientation of the problem/issue approach. Data requirements increase as the planning processes become more sophisticated.
   (d) Some lessening of data needs for physical and operating data can be detected as freight planning becomes more sophisticated. This reflects the fact that Priority II and III issues are less physically oriented, more economic or policy oriented in character and thus require different sets of data.
   (e) With one exception, a general lessening of data needs for direct and indirect impacts can be detected as freight planning progresses in sophistication. The exception is an increasing need for data reporting economic impacts. The relatively low requirement for energy consumption data can be attributed to the fact that most problems/issues are not directly concerned with energy consumption *per se*. This, of course, could change should fuel again become scarce.

TABLE 5

FREQUENCY DISTRIBUTION OF ISSUES BY PRIORITY, BY MODE

MODE	PRIORITY			
	HIGH	MEDIUM	LOW	ALL
Rail	6	13	6	25
Motor carrier	5	7	4	16
Port	0	7	5	12
Inland waterway	0	3	6	9
Air cargo	0	1	7	8
Pipeline	0	0	4	4
All	11	31	32	74

Data Needs Through Examination of Planning Methods

Five kinds of planning activities were examined in detail: demand forecasting, modal choice analysis, network analysis, economic evaluation, and impact estimation. The examination was for three main purposes: (1) to identify the likely planning activities by stage, (2) to determine data requirements, and (3) to assess the current state of the art. Each of the five activities was found to have a sizable number of technical methods or models within it, some fairly standard or well-perfected, others largely untested or experimental. In some cases, numerous alternative techniques existed; in others, relatively little methodology had been adopted.

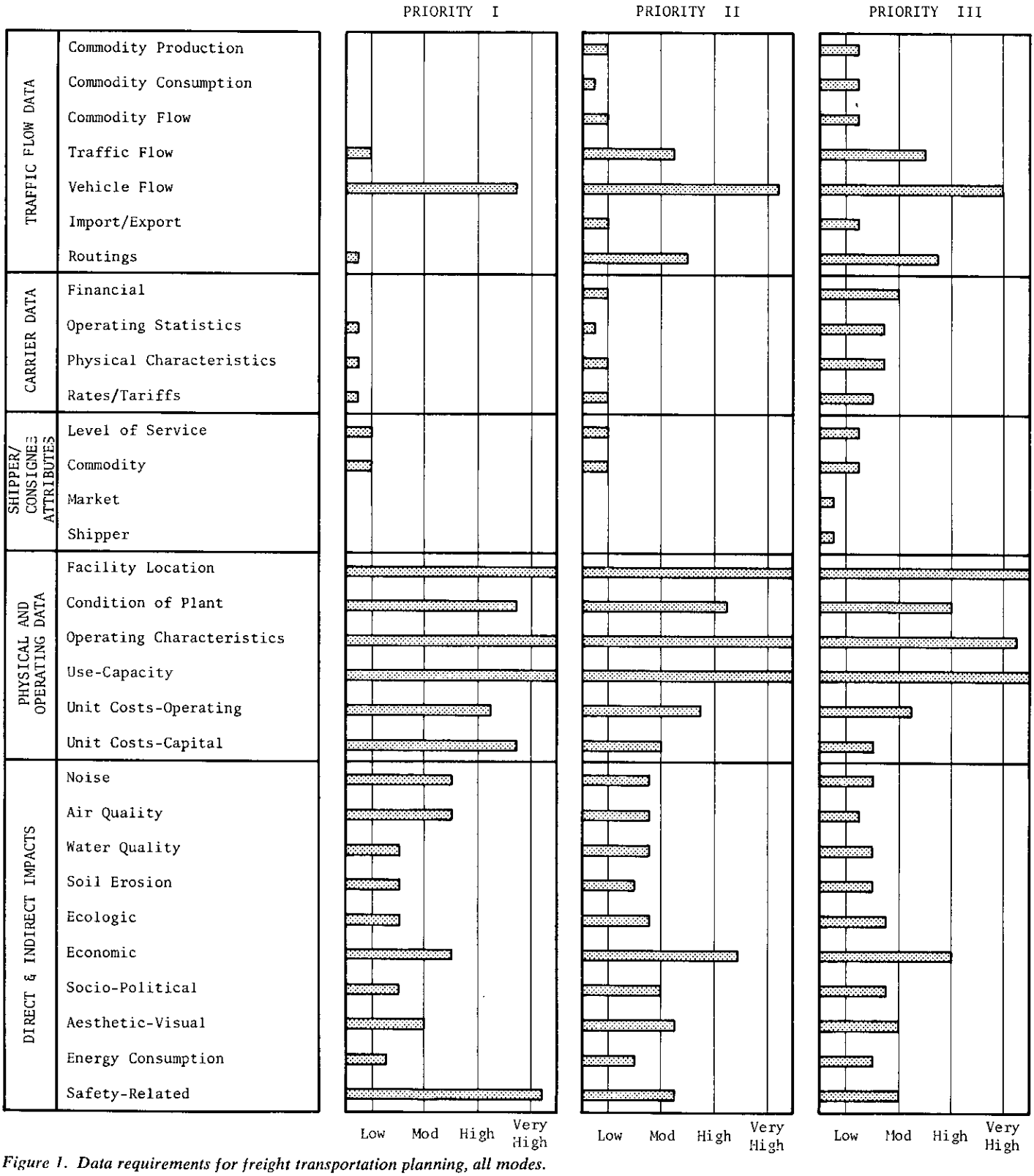

Figure 1. Data requirements for freight transportation planning, all modes.

As states develop increased skill and capability, they will shift from reliance on very simple methodologies to the increasing use of comprehensive, quantitative techniques. This will occur in stages, as defined in Table 6.

Table 7 lists likely planning activities by the three planning stages. Table 8 lists the corresponding data needs by stage, as derived through examination of planning methods. Underlying the identified data needs is an assessment of the current state of the art and the utility of existing planning methods in conducting statewide freight transportation systems planning. The key findings are summarized in the following. Also included are references to tabular and descriptive material on data contained in the appendixes.

TABLE 6

DEFINITIONS OF PLANNING STAGES

PLANNING STAGE	DEFINITION
I	Initial stage. Involvement largely limited to obtaining an initial familiarity with the freight transport system and its economic implications. Planning largely an individual response to particular problems or issues. Some broad-scale, policy-level planning. Data requirements limited to readily available secondary source data concerning network characteristics and use.
II	Intermediate stage. Developing a systems planning capability. Initial use of analytical techniques for forecasting demand, estimating modal choice, assessing economic effects, and estimating impacts for comprehensive freight planning. More sophisticated, quantitative response to particular problems or issues. Deeper understanding of factors influencing demand and mode choice. Data requirements mandate the acquisition and use of a majority of the listed data sources.
III	Advanced stage. Full development of a comprehensive freight transportation systems planning process. Full-scale application of the more sophisticated techniques for demand estimation, mode split, network analysis, economic evaluation, and impact estimation. Data requirements include the listed data sources plus other sets of primary and secondary data.

Demand Forecasting

A variety of forecasting methods was examined, as described in Appendix B. Some of these methods are quantitative, a few are based on time series and projections, and others are largely qualitative. Four methods were identified as being of greatest use to state planners in forecasting freight demand: (1) regression analysis techniques, (2) econometric models (simultaneous equation systems), (3) input-output models, and (4) economic base studies. These methods themselves are standard and have been in existence for a long time. Except for regression analysis techniques, their application to forecasting freight demand is relatively recent. Forecasting done to date was found to be largely (1) short-range, (2) national or corporate in scope, (3) trend oriented, and (4) dependent on historical commodity or traffic flow data. A strong need was found to incorporate macroeconomic data and indices of anticipated future economic performance into demand forecasting procedures as well as long-term locational, technological, and transport cost and service factors.

A key finding was the interdependency of freight or commodity flow and macroeconomic data in forecasting—that freight demand forecasts can be no better than estimates of total economic growth and change. Trend extensions and simple correlations of traffic flow data with macroeconomic variables, which represent the current state of the art, must ultimately be replaced by more advanced techniques that take into account economic interdependencies, differential regional growth and specialization, and technological change if significant improvements are to be made in tactical (short-range) and strategic (long-range) forecasts. Better data obviously are important to improving present demand forecasting capabilities at both the national and state level.

Appendix B contains descriptive and tabular material that can aid the planner in preparing freight forecasts and determining data needs and availability. Several forecasting methods were reviewed in detail, including (1) the USDOT Input-Output Model for national projections, (2) Polenske's Multiregional Input-Output Model for state projections, (3) forecasts made for economic areas by the U.S. Bureau of Economic Analysis, and (4) economic base studies for regional forecasts. Major national freight demand projections, which states can use as bases or checks for their individual projections, are described in Figure B-8. Data needed for economic base studies are specified in Figure B-2. Multiregional Input-Output Model data tapes available from USDOT are listed in Figure B-9. Stage I, II, and III data requirements for demand estimation are listed in Table B-1.

Mode Choice Analyses

A large number of mode split models falling into eight categories were examined, as described in Appendix C. These categories include (1) macroeconomic, (2) inventory theoretics, (3) regression analysis, (4) abstract mode, (5) linear programming, (6) discriminant analysis, (7) logit, and (8) probit models. The models described have at best been tested only on a limited basis. Hence, their feasibility or practicality has not been determined. No concensus, evidently, has developed over which method is best. No method has been applied to the solution of a specific, state-level freight issue or problem. The lack of application and the inconclusiveness of results obtained is usually attributed to problems of data availability.

Key findings include (1) the interdependency of data and theory, (2) the lack of consensus among professionals on both data and theory, and (3) the fact that even were agreement reached, much developmental work remains to be done before mode choice models can be readily applied by state planners to statewide freight transportation systems planning. Underlying the lack of consensus are many major unresolved issues that have a direct bearing on data requirements. These include (1) whether to use aggregate or disaggregate modeling techniques, (2) agreement on

TABLE 7

PLANNING ACTIVITIES, BY STAGE

STAGE I
Demand forecasting. Prepare short-range freight demand estimates for individual modes using trend extension techniques, combining demand forecasting and modal split via modal traffic flow data extrapolation.
Modal choice analysis. Develop capability to prepare total demand estimates by individual mode using historical trend extrapolation techniques and linear probability functions.
Network analysis. Develop capability to inventory freight modal networks and prepare network maps of each mode.
Economic evaluation. Assemble published information on costs, rates, and time.
Impact estimation. Prepare aggregate order-of-magnitude estimates of energy consumption or emission production (air pollution only).
STAGE II
Demand forecasting. Prepare short-range aggregate forecasts using structurally based forecasting techniques (e.g., regression analysis) based on projected changes in the national and state economies.
Modal choice analysis. Prepare interregional demand estimates by aggregate commodity groupings by individual modes using mathematically based freight modal split modeling techniques, such as the abstract-mode or commodity approach.
Network analysis. Prepare macro-level estimates of interregional traffic flows using modeling techniques or manual processes.
Economic evaluation. Assemble alternate sets of data on costs, rates, and time.
Impact estimation. Estimate noise pollution impacts and more detailed estimates of consumption, energy, and air pollution impacts by incorporating details on the physical and operating characteristics of the transportation system.
STAGE III
Demand forecasting. Prepare aggregate traffic flow forecasts from separate commodity production and consumption estimates. Projections would (1) be mode independent, (2) be tied into econometric models projecting state-level or regional economic activity, and (3) account for locational, technological, and transport cost or service considerations not possible with time-series projection methods.
Mode choice analysis. Develop capability to prepare intercounty commodity flow estimates by individual modes using disaggregate behavioral mode choice models (logit, probit, and discriminant analysis functions).
Network analysis. Prepare individual link and node traffic estimates by commodity type.
Economic evaluation. Synthesize cost and rate information, which would then largely replace the use of historically based data sets, and develop computerized procedures to be used in generating cost, rate, and time data.
Impact estimation. Simulate freight system energy consumption and emissions production impacts on a statewide or corridor basis and covering all modes, incorporating extensive data on the physical characteristics and operating practices of the different modal systems.

what constitutes the relevant variables to be included, (3) the "level" at which such modeling should take place (for the individual firm or for all firms within a geographic area), and (4) the degree of homogeneity required in the data and whether different commodity groups must be modeled separately. Further work in developing modal choice models must be hand in hand with improvements to commodity or traffic flow data availability and characteristics.

Appendix C contains several tables of interest to the state planner, in addition to the review of freight modal selection models. Table C-1 gives shipper, market, commodity and transport level-of-service attributes sought in data for mode choice modeling purposes. Stage I, II, and III data requirements are given in Table C-3. Finally, the section reviewing mode choice models and their data requirements offers helpful insights into the problems involved in matching theoretical models with data availability and data characteristics.

Network Analyses

Several modeling techniques for conducting macro-scale freight transportation system network analyses were examined, as described in Appendix D. These methods generally were found to be of two types. The first group are traffic assignment procedures that can be mathematically derived or simulated by existing computerized assignment processes, such as minimum-path algorithms. The second group are models that presently are not applicable to computerized assignments. For simplicity, the former group was classified as mechanical processes and the latter group as manually derived assignment models. Only a few models have been applied to help resolve specific state-level freight issues or problems. This lack of application is usually attributed to problems of data availability.

The key finding was that mechanical assignment methods must be further developed to depict more realistic routings of freight traffic. Better understanding of the logistics of

TABLE 8

DATA REQUIRED FOR FREIGHT SYSTEM PLANNING, BY CATEGORY, BY STAGE

DATA CATEGORY	DATA REQUIREMENTS
STAGE I	
Traffic flow data	1. Estimates of annual state and national modal traffic flow data, in tons and ton-miles, compiled from secondary sources, such as the Carload Waybill Statistics, *Census of Transportation*, Waterborne Commerce of the U.S., FHWA truck survey data.
Modal forecasts	1. Historical trends and modal forecasts of national modal distributions by year, average length of haul in mileage blocks, average shipment size. Obtained from governmental agencies, trade associations, etc.
Network parameters	1. Schematic network maps showing link lengths and nodal characteristics.
National and state economic forecasts	1. Publications of state and federal governments, trade associations, and major industries forecasting economic growth, trends and outlook on a recurring basis.
Costs and rates	1. Average operating costs and revenues for different mileage and tonnage blocks (from published sources). 2. Typical unit capital costs for different modal investments. 3. Class rates.
Impact data	1. Fuel consumption and air pollutant emission rates, by mode.
STAGE II	
Traffic flow data	1. Annual traffic flows between state regions and between state and national regions (states), by commodity types.
Modal forecasts	1. Projections made by major carriers serving the state. 2. Average shipment size and average value per ton, by commodity grouping. 3. Distance and transit time between zonal pairs, by mode.
Network parameters	1. Detailed maps for each node showing link distances, travel times, and interzonal routings.
State economy	1. Detailed economic growth forecasts, by county or substate region. 2. Historical data for various years on commodity production and consumption, by region assembled from various agencies.
Costs and rates	1. Operating costs and revenues, from sample surveys of waybills. 2. Average unit capital costs, from sample surveys of specific modal investments.
Transport time and time reliability	1. Sample surveys of total transit time (e.g., waybill studies). 2. Length of haul by shipment, line-haul time, transfer time, delivery time from analytic models. 3. Standard deviation of shipment times.
Impact data	1. Fuel consumption per horsepower-hour. 2. General operating characteristics (average vehicle size, operating speed, trips per day). 3. Air pollution emission rates for different power units. 4. Existing pollution levels. 5. Population near segment.
STAGE III	
Traffic flow data	1. Disaggregate commodity traffic flows between county pairs and between counties and other states or multi-state areas.
Modal forecasts	1. Shipment weights and value per ton, by detailed commodity grouping. 2. Transit time and rates (see below).
Network parameters	1. Network suitable for computer processing, detailed link parameters, and detailed node parameters.
State-level economic information	1. Inputs and outputs from specially developed economic model of the state's economy from state, national, or private sources.
Costs and rates	1. Detailed operating cost data (comparable to that available to carriers and regulatory agencies.) 2. Detailed unit capital costs similar to those developed by Bechtel for USRA. 3. Tariff rules and schedules.
Transit time and time reliability	1. Time obtained through field measurements.
Impact data	1. Train performance calculators and other models that simulate operations. 2. Physical characteristics of route. 3. Ambient air, water, and noise levels along routes. 4. Air and noise dispersion models. 5. Accident rates, by mode and commodity grouping.

individual freight movements by mode and aggregate commodity type is needed. Only then will state planners be provided with the kinds of data required for freight transportation system network analysis. The development of better network models is directly related to improvements in traffic flow data availability. Presently, most network models do not provide uniform data coverage of the different modes.

Appendix D contains several tables of interest to the state planner, in addition to the review of freight network analysis models. Table D-1 lists the types of data needed for network analyses purposes. These data include: (1) network parameters for each transportation facility segment and node, (2) interzonal traffic flow information, and (3) detailed routing data. Stage I, II, and III data requirements are listed in Table D-2.

Economic Evaluation

Methods for conducting economic evaluations are quite standard and well known, and hence were not reviewed *per se*. However, to apply such methods requires cost, revenue, transport time, and time reliability data. The challenge was found to lie primarily in assembling proper cost and revenue information. A wide variety of methods for transforming cost and rate data into summary information suitable for use in transportation systems planning was examined, as described in Appendix E. Four methods were identified for cost compilation: (1) the USRA's procedure for costing the rehabilitation of railroad lines and facilities, (2) ICC "Rail Form A" cost calculations, (3) barge line costing procedures being developed by the U.S. Army Corps of Engineers, and (4) USDOT Transportation Systems Center's procedure for estimating operating costs. Four methods were similarly identified for assembling information on freight revenues or rates: (1) using detailed revenue data, when available; (2) collecting actual rates and tariffs from carriers and regulatory agencies; (3) substituting proxy data; and (4) developing rate generating models. Several procedures for measuring transport time and time reliability were also identified.

The key finding was that methods for developing cost, rate, transport time, and time reliability information must be further developed to provide the kinds of data required for transportation systems planning. Cost and rate data are so specialized, difficult to understand, and changeable over time as to effectively preclude direct state involvement with original data sets. In short, the probability of error is too high to permit such an approach. Simplified methods were found to be an effective solution if done on a centralized basis by an agency or organization having the required expertise and interest in providing the service to state DOT's on a continuing basis.

Appendix E contains sample products from the listed methods for developing cost and rate information. These simply serve to illustrate the types of data that can be generated. Stage I, II and III data requirements for economic evaluation are listed in Table E-1.

Impact Estimation

A diverse group of techniques for estimating energy consumption, vehicle emissions, noise levels, and water quality effects of freight transportation was examined, as described in Appendix F. The techniques were found to be of three types. The first group consists of generalized measures related only to the unit consumption of energy or production of pollutants. The use of such measures is straightforward; the factor is simply multiplied by some production measure, such as net ton-miles, hours, or gallons of fuel consumed. The second group consists of computations based on physical relationships, such as resistance equations and propulsive work. The third group is largely based on empirical observations and measurements. Impact computations can be refined through incorporating additional vehicle, roadbed, and operational factors into the computations.

The key finding was that impact estimation techniques, although originally developed primarily for application at the project level, can be adapted to use in systems planning to the extent that supporting traffic, operating, and physical data are available, as well as information on ambient conditions necessary to determine air, noise, and water pollution impacts. Further, a need was found for more refined estimates of unit energy consumption and emissions productions to more closely simulate actual conditions. The available procedures do not provide uniform coverage of the different modes and impacts. Much work remains to be done to fill in the voids.

Appendix F contains descriptive and tabular material that can aid the planner in estimating impacts. Table F-1 lists the factors affecting energy consumption. Figure F-2 gives estimates of the energy intensiveness for different modes. Figure F-4 gives locomotive fuel consumption rates. Figure F-5 presents pipeline energy intensiveness values. Figures F-7, F-8, and F-9 give locomotive, diesel truck, and vessel emission factors. Stage I, II and III data requirements for impact estimation are listed in Table F-2.

DATA AVAILABILITY

Substantial data resources exist that can be used for statewide freight transportation systems planning. These data are not all in the form or in the degree of detail needed for planning purposes, nor are the various data files consistent as to type or degree of geographic detail so as to make them easy to use. Nevertheless, there is much information available.

The research found 77 principal data sources, 114 other sources, and 34 reference sources, as catalogued in Appendix C of the User's Manual (*NCHRP Report 178*). Four basic criteria were employed to select the sources to be included in this catalogue. The first criterion is usefulness in the methods needed to respond to freight problems/issues. Second, the data must be national data, not pertaining to just a few states or to a locality. Third, the data must be from either a recurring data collection program or from a recent one-time study. Finally, a comprehensive rather than restrictive approach was adopted in selecting data sources; if there was a doubt, the source was included.

By including a large number of sources, a planner can choose the one best suited to the needs at hand. For convenience and efficiency, the data files were grouped into the following three categories:

- *Principal data sources.* Major, regularly collected data sources most often required for statewide transportation planning purposes. Emphasis on original data sources, either hard copy or a form suitable for computer processing, rather than statistical summaries or information obtained from other sources and further summarized. Sources contain strictly freight-transport-oriented data.
- *Other data sources.* Less significant data sources having one or more of the following characteristics: (1) data on production or consumption, or otherwise not strictly freight-transport-oriented; (2) statistical summaries of data from various sources, such as modal trends, facts, and/or figures; (3) major one-time studies, or studies conducted on an irregular basis; (4) less significant and important data sets as judged by their potential use in statewide planning; and (5) data on highly specialized phases or aspects of freight transport.
- *References.* Tools needed to understand and interpret freight data, including codes, definitions, guidebooks, manuals, and other data-related publications.

The number of data sources found for each data category is given in Table 9. In general there are data series relating to most of the data categories required by statewide freight transportation planning. Documentation varies in detail, but all items in the catalogue are described by title, mode, type of data, publication cycle, and issuing source. All sources have an abstract and utilize a set of key words to describe the content. Principal data source descriptions have more information, including (1) the collecting agency, (2) the form of the data, (3) time period covered, (4) coverage, (5) relevant content of the source file, (6) available summaries, (7) a description of the data collection process, (8) significant exclusions of data, (9) future update or extension plans, (10) data availability and constraints on dissemination, and (11) an evaluation of the data source as to its usefulness in statewide freight transportation systems planning.

Given the extensiveness of the data sources listed in Appendix C, of the *User's Manual* (*NCHRP Report 178*), priorities must obviously be set for acquiring needed sources. Table 10 is an index of data sources referenced by planning stage, mode, and recommended order of acquisition. Sources marked with an asterisk are considered essential sources; those not so marked are either a duplication of essential sources or represent data that are not considered to be essential to statewide freight transportation systems planning.

TABLE 9

FREIGHT DATA SOURCES, BY DATA CATEGORY

DATA TYPE	CATEGORY	SOURCES: PRINCIPAL	SOURCES: OTHER	SOURCES: REFERENCES
Traffic Flow	Commodity production	5	23	0
	Commodity consumption	3	12	0
	Commodity flow	3	5	1
	Traffic flow	24	16	0
	Vehicle flow	4	2	0
	Import-export	2	6	0
	Routings	6	6	0
Carrier	Financial	25	12	3
	Operating statistics	32	21	0
	Phys. characteristics	18	21	3
	Rates/tariffs	5	2	1
Shipper/ Consignee Attributes	Level of service	2	1	0
	Commodity	2	1	0
	Market	3	0	0
	Shipper	9	3	0
Physical and Operating Data	Facility location	13	16	3
	Condition of plant	2	2	0
	Oper. characteristics	16	30	3
	Use-capacity	6	0	0
	Unit costs, operating	1	8	0
	Unit costs, capital	0	3	0
Direct and Indirect Impacts [a]	Noise	0	2	0
	Air quality	0	2	0
	Water quality	0	1	0
	Soil erosion	0	0	0
	Ecologic	0	0	0
	Economic	0	8	0
	Socio-political	0	0	0
	Aesthetic-visual	0	0	0
	Energy consumption	0	4	0
	Safety related	0	0	0
General		0	7	22
Total [b]		77	114	34

[a] The search for data of these types was not exhaustive inasmuch as most impacts are of a highly localized nature and data for such impacts are local rather than national in origin.

[b] Totals do not add because any data source may contain data in several categories.

UNMET DATA NEEDS

For each of the 31 data categories listed in Table 11, assessments were made of present freight data availability and quality. These assessments considered:

- *Form of the data.* Whether the typical format of available secondary data and the associated units of measure readily lends itself to statewide freight transportation planning purposes.
- *Availability.* The general accessibility of the data for state use, including (1) anticipated difficulties in obtaining access to the data, (2) the need to seek the data from multiple sources, and (3) the amount of staff effort involved in assembling the data into a usable form.
- *Characteristics.* The general parameters of the data, such as (1) aggregation, (2) modal variability, (3) coding systems, and (4) level of detail.
- *Deficiencies.* The degree to which available data sources meet data needs, especially: (1) the completeness of the data; (2) over-all quality, including reliability, workmanship, consistency, uniformity, and age; (3) level of aggregation, especially geographic; (4) modal coverage or lack thereof; (5) immediate usefulness of the data in supporting state DOT efforts to build internal expertise; and

TABLE 10

INDEX OF FREIGHT DATA SOURCES REFERENCED, BY PLANNING STAGE, MODE, AND ORDER OF ACQUISITION

Ref. No.	Short Title
	STAGE I
	Railroad
P/A/61	*U.S. Transportation Zone Maps
O/I/33	*Official Rail Guide, No. Amer. Freight Services
O/I/36	*Railroad Mileage by States
O/I/48	*Yearbook of Railroad Facts, 19xx
P/G/06	*Railroad Company System Maps
P/G/08	*Railroad System Traffic Density Maps
O/I/41	*Statistics of Railroads of Class I in U.S.
O/I/38	Rank of Class I Railroads
O/I/04	American Short Line Railway Guide
O/I/17	Handy Railroad Atlas of the United States
R/A/12	Uniform System of Accounts for Railroad Companies
R/I/13	Price List of AAR Publications
	Motor Carrier
O/I/08	*ATA American Motor Carrier Directory, National Edition
O/I/20	*Intercity Truck Tonnage, 19xx
O/I/05	*American Trucking Trends, 19xx
O/I/26	*Motor Truck Facts, 19xx
O/A/49	*Highway Statistics, 19xx
O/I/40	*Stand. Hwy. Mileage Guide on H'hold Goods Carriers
P/A/13	*Census/Transportation Truck Inventory/Use Survey
R/I/10	Natl. Dist. Dir.-Local Cartage-Short-Haul Cars. Wrhsg.
R/I/03	American Trucking Association Publications List
	Air Cargo
O/I/10	*Official CAB Airline Rte-Maps-Airport to Airport Mlgs.
O/I/02	*Air Transport
R/I/02	*Air Cargo from A to Z
O/I/01	*Air Cargo Guide
O/A/47	FAA Statistical Handbook of Aviation, 19xx
	Waterway/Ports
P/A/02	*Inland Navigation System Maps
P/A/03	*Map Inland Waterways Freight Tonnage
O/I/21	*Interstate Port Handbook, 19xx
P/G/05	*Port Authority Facilities Reports
O/A/11	Transportation Series
O/I/24	Map-Commercially Navig. Inland Waterways of U.S.
O/A/20	Essential U.S. Foreign Trade Routes
	Pipelines
P/I/01	*Atlas/Crude-Oil Pipelines of U.S. and Canada
P/I/02	*Atlas/Products Pipelines of the United States
O/A/31	*Crude-Oil and Refined-Products Pipeline Mileage in U.S.
	TOFC/COFC
O/A/41	*Study of TOFC Operations
O/I/33	*Official Rail Guide, No. Amer. Freight Services
O/I/48	*Yearbook of Railroad Facts, 19xx
	Multi-Modal
O/A/55	*Summary of National Transportation Statistics
O/I/43	*Transportation Facts and Trends, 19xx
P/A/59	National Transportation Study
R/A/10	Statistical Abstract of the United States
R/A/06	Historical Stats. of the U.S.-Colonial Times to 1957
O/A/37	Intercity Ton-Miles, 1939-1959
R/I/05	Commercial Atlas and Marketing Guide
	Non-specific
R/A/14	*Standard Transportation Commodity Description and Code
	STAGE II
	Railroad
P/G/09	*Railroad Track Charts
P/G/07	*Railroad Employee Timetables
P/A/55	*Railroad Carload Waybill Sample

Ref. No.	Short Title
	STAGE II (con't.)
P/A/62	*Interline Revenue Settlement Data
P/A/46	*Form QCS, Class I RR;s Qtr. Rept.-Frt. Commodity Stat.
O/A/61	*USRA NE Railroad Prog. Rehab. Planning Master File
O/A/60	*USDA NE Railroad Prog. Field Inspection Master File
P/A/32	*Form R-1, Class I Railroads Annual Report
P/A/33	*Form R-2, Class II Railroads Annual Report
O/A/40	*Railroad Carload Cost Scales, 19xx
O/A/39	*Rail Rev. Contribution by Commodity & Territory, 19xx
O/A/54	*Short Line Mileages
R/I/16	*Standard Point Location Code
R/I/06	*Freight Station Accounting Code Directory
O/A/35	*Circuity of Rail Carload Freight
R/I/01	AAR Standard Route Code
P/A/24	RR Agent's Report-Shipments of Minerals/Products
P/I/03	Revenue Freight Loaded by Commodities
P/A/39	Form OS-A, Class I RR's Qtr. Rept.-Yard/Train Services
P/G/11	Railroad Through Freight Schedules
R/I/12	Official List of Open and Prepay Stations
O/I/37	Railway Line Clearances Including Weight
O/I/32	Official Railway Equipment Register
P/A/58	Natl. Railroad-Highway Grade Crossing Inventory
P/A/27	Form F-1, Class A Freight Forwarders Annual Report
O/A/38	Invest. of RR Freight Route Structure, Ex Parte 270
O/I/14	Freight and Passenger Traffic Density, Class I RR's-West. District
O/A/26	Waterborne Shipping Market Analysis Master File
O/G/02	Situation Reports
O/G/03	Railroad Company Valuation Maps
O/G/04	Railroad Yard Diagrams
O/G/01	DICCS Maps
R/I/04	Car Hire Master List
R/I/08	Manual for Railway Engineering
O/A/06	Freight Car Supply Problem and Car Rental Policies
O/A/08	Livestock Transportation Survey
	Motor Carrier
P/A/60	*Truck Weight Study
P/A/34	*Form TCS, Freight Commodity Statistics, Annual Report
P/A/28	*Form M-1, Class I Motor Carrier of Prop. Annual Report
P/A/29	*Form M-2, Class II Motor Carrier of Prop. Annual Report
P/A/30	*Form M-3, Class III Motor Carrier of Prop. Annual Report
O/A/36	*Cost of Transportation Freight-Class I-II MC's-Gen. Commodities
P/G/03	*Motor Carrier Continuing Traffic Studies
R/I/16	*Standard Point Location Code
O/I/44	*Trinc's Blue Book of the Trucking Industry
O/A/52	*Nationwide Truck Commodity Flow Study
O/A/48	Highway Freight Flow Study
O/I/45	Truck Taxes by States
O/I/34	The Owner-Operator: Independent Trucker
O/A/44	Comp.-Intercity Freight Market-Waybill Study of MC Industry
P/A/27	Form F-1, Class A Freight Forwarders Annual Report
P/A/58	National Railroad-Highway Grade Crossing Inventory
O/I/09	ATA American Motor Carrier Directory, Spec. Services Edition
P/A/56	Test Study Distribution of Shipments/Weight
O/A/09	Livestock Trucker Survey II
O/A/08	Livestock Transportation Survey
	Air Cargo
P/A/57	*FAA Airport Master Record Forms 5010-1,-2
O/I/30	*Official Airline Guide
P/A/07	*Air Freight Origin-Destination Study
P/A/08	CAB Service Segment Statistics
P/A/11	Scheduled All-Cargo Services
O/I/12	CTOL Transport Aircraft char./trends
O/A/46	FAA Air Traffic Activity
O/I/13	Digest of Statistics, Traffic Flow
O/I/42	Transoceanic Cargo Study Master File

* Essential data source. Ref. No. -- 1st digit: P=principal data source; O=other data source; R=reference.
2nd digit: A=public agency; I=private organization or individual; C=general.
3rd digit: Listing order found in Table C-3 of User's Manual (NCHRP Report 178).

Ref. No.	Short Title
	STAGE II (con't.)
	Waterways/Ports
P/A/05	*Port Series-Part II
P/A/06	*Waterborne Commerce Statistics
P/A/35	*Form W-1, Class A-B Carriers-Waterways, Annual Report
P/A/36	*Form W-3, Class C Carriers-Waterways, Annual Report
P/A/37	*Form W-4, Maritime Carriers Annual Report
O/A/51	*List of Lights and Other Marine Aids
R/A/03	River Pt. Dir., Miss. River-Gulf Coast Inland Waterways System
O/I/19	Inland Waterborne Commerce Statistics, 19XX
O/I/16	Greenwood's Guide to Great Lakes Shipping
O/A/56	Traffic Report of the St. Lawrence Seaway, 19XX
O/A/26	Waterborne Shipping Market Analyses Master File
P/A/17	Ship Data System
O/A/10	Petroleum Transportation System Study
O/I/42	Transoceanic Cargo Study Master File
O/A/43	Barge Mixing Rule Study
R/A/07	List of Barges Specially Designed-Carried on Other Ves.
O/A/22	Inventory of American Intermodal Equipment
	Pipelines
O/I/27	*NPC: Report of Committee on Oil and Gas Trans. Facilities
O/I/46	*U. S. Petroleum and Gas Transportation Capacities
P/A/23	*Pipeline Products Report
P/A/31	*Form P, Carriers by Pipeline Annual Report
O/A/29	Statistics of Interstate National Gas Pipeline Cos.
O/A/27	Cost of Pipeline and Compressor Station Construction
O/A/30	United States Imports and Exports of Natural Gas
	TOFC/COFC
O/I/31	*Official Intermodal Equipment Register
O/A/40	*Railroad Carload Cost Scales, 19XX
O/A/50	Intermodal Cargo Study
O/A/35	Circuity of Rail Carload Freight
P/I/03	Revenue Freight Loaded by Commodities
O/A/22	Inventory of American Intermodal Equipment
	Multi-modal
P/A/12	*Census/Transportation Commodity Trans. Survey
P/A/15	*Domestic/International Transportation-U.S. Foreign Trade
O/I/27	*NPC: Report of Committee on Oil and Gas Trans. Facilities
O/A/58	*TSC Intercity Freight Flows File
O/A/23	National Network Simulation Model Traffic Flow File
O/A/53	Selected Statistics-Distance Hauls of Freight by Mode
O/A/42	Transport Economics
O/I/39	Shifts in Petroleum Transportation
O/A/57	Transportation Projections: 1970-1980
O/A/05	Dry Granular Fert. and Formula Feed Transport Survey
	Non-specific
R/I/17	*Standard Transportation Commodity Code
R/A/13	*Standard Industrial Classification Manual
R/I/14	*Standard Carrier Alpha Code
R/A/04	*Commodity Transportation Survey Expansion Proj.-Phase I
O/A/45	*Energy Statistics-Supplement to Summary of National Transportation Statistics
R/I/11	National Motor Freight Classification
R/I/19	Tariff Guide No. 7
R/I/07	Hazardous Material Code
	STAGE III
	Railroad
P/I/04	*TeleRail Automated Information Network - II
P/G/01	*Railroad Abandonment Applications
O/I/18	*Indices of RR Material Prices and Wage Rates, Class I RR's
O/I/23	*Keystone Coal Buyers Manual
R/I/18	*Studies in Railroad Operations and Economics
P/G/10	*Railroad Waybills
P/A/26	Forms A-B, Monthly Report RR Employees, Serv. & Comp.
P/A/40	Form OS-B, Class I RR's Qtr. Report-Oper. Statistics, Revenue Traffic
P/A/41	Form OS-C, Class I RR's Qtr. Report-Oper. Statistics, Pwr/Equip.
P/A/50	Form QL, & D-R, Qtr. Report Freight Loss/Damage, Class I RR's
P/A/44	Form PTR-R, TOFC Traffic Term.-Class I RR's/Car Movements
P/A/53	Form RBO, Rate Bureau/Organizations Annual Report
P/A/54	Form RE, & I, Qtr. Report Rev./Exp./Inc. Class I RR's
P/A/38	Form CBS, Class I RR's Qtr. Cond. Balance Sheet

Ref. No.	Short Title
	STAGE III (con't.)
	Motor Carrier
O/I/29	*NCHRP 33-Values of Time Savings of Commercial Vehicles
P/G/04	*Motor Carrier Waybills
P/A/48	Form QFR, Class I-II Motor Car. of Prop.-Qtr. Rept. Rev.
P/A/49	Form QL & D, Qtr. Report Freight Loss/Damage, Class I MC's
P/A/43	Form PTR-M, TOFC Traffic-Class I Motor Carriers of Prop.
P/A/53	Form RBO, Rate Bureau/Organizations Annual Report
O/A/04	Cost of Operating Trucks for Livestock Transportation
	Air Cargo
P/A/10	*Financial/Operating Report-Cert. Air Carriers
P/G/02	*Uniform Airbills
P/A/09	*Financial/Operating Report-Air Freight Forwarders
	Waterways/Ports
P/A/04	*Performance Monitoring System
O/I/23	*Keystone Coal Buyers Manual
P/A/52	*Form QWS, Qtr. Report Water Carriers Revenue Traffic
P/A/14	Container Utilization
P/A/25	Tanker/Barge Shipments PAD III-Crude Oil/Petroleum
P/A/16	Foreign Trade System
P/A/45	Form PTR-W, TOFC Traffic Term.-Class A Water Carriers
O/A/07	Grain Market News
	Pipelines
P/A/51	*Form QPS, Quarterly Report of Pipeline Companies
O/A/28	Gas Supplies of Interstate Natural Gas Pipeline Cos.
O/I/15	Gas Facts
	TOFC/COFC
P/A/43	*Form PTR-M, TOFC Traffic-Class I Motor Carriers of Prop.
P/A/44	*Form PTR-R, TOFC Traf. Term.-Class I RR's/Car Movements
P/A/45	*Form PTR-W, TOFC Traf. Term.-Class A Water Carriers
P/A/42	*Form PTR-FF, TOFC Traf. Orig. Class A Freight Forwarders
	Multi-modal
P/A/21	*Bureau of Mines Repetitive Commodity Surveys
P/A/22	*Distribution of Bituminous Coal/Lignite Shipments
P/A/01	*Fresh Fruit/Vegetables Shipment Master File
O/A/25	*U.S. Multiregional Input-Output Data File
O/I/11	*Coal Traffic Annual
P/A/20	Bituminous Coal/Lignite Production and Mine Operation
P/A/18	U. S. Exports-Schedule B, Master File
P/A/19	U. S. Imports for Consumption/General Imports Master
O/A/33	Mineral Facts and Problems
O/I/06	Annual Statistical Report
P/A/47	Form QFF, Class A Freight Forwarders Qtr. Report of Revenues
P/A/42	Form PTR-FF, TOFC Traffic Orig. Class A Freight Forwarders
	Non-specific
R/A/02	*Guide to USDA Statistics
O/A/03	*Annual Summary of Crop Production, 19XX
O/A/59	*U. S. Multiregional Input-Output Data File
O/A/21	*Input-Output Structure of the U. S. Economy
O/A/01	*Agricultural Statistics, 19XX
O/I/35	*Petroleum Facts and Figures
O/A/14	Census of Mineral Industries
O/A/12	Census of Agriculture
O/A/13	Census of Manufacturers
O/A/18	County Business Patterns
R/A/09	Schedule B-Stat. Class. of Domestic & Foreign Commodities Exp. U.S.
R/A/08	Schedule A-Stat. Class. of Commodities Imported-U.S.
R/I/15	Standard Definitions for Petroleum Statistics
R/I/20	United Nations Standard Intl. Trade Classification
O/A/32	Fuel and Energy Data, U.S., by States and Region
O/A/34	U. S. Mineral Resources, Geological Survey
O/I/07	Annual Statistical Review
O/I/22	Iron Ore
O/A/17	Census of Wholesale Trade
O/A/16	Census of Retail Trade
O/A/15	Census of Population and Housing
O/A/24	Survey of Current Business
R/A/05	County and City Data Book
R/A/01	Agricultural Outlook
R/A/11	National Petroleum Product Supply and Demand, 19XX
O/I/49	Yearbook of the American Bureau of Metal Statistics
O/I/28	National Petroleum News Factbook, 19XX
O/I/25	Metals Statistics
O/I/03	Aluminum Statistical Review
R/I/09	Moody's Transportation Manual
O/I/47	Weekly Statistical Bulletin of API
O/A/02	Interregional Analysis-U.S. Grain-Mktg. Industry
O/A/19	Enterprise Statistics

TABLE 11

OVER-ALL CRITICALITY OF DEFICIENCIES, BY CATEGORY

	Data Category	Frequency that Data Are Req'd. for Transportation Systems Planning: Issues and Problems Approach	Frequency that Data Are Req'd. for Transportation Systems Planning: Quantitative Methods Approach	Over-all Deficiency Assessment, Table H-1	Criticality of Deficiency and Unmet Data Needs
TRAFFIC FLOW DATA	Commodity Production	Low	Moderate	Minor	Low
	Commodity Consumption	Low	Moderate	Minor	Low
	Commodity Flow	Low	High	Major	High
	Traffic Flow	Moderate to High	High	Major	Very High
	Vehicle Flow	Very High	High	Minor	Moderate
	Import/Export	Low	Low	Minor	Low
	Routings	Moderate to High	Moderate	Moderate	Moderate to High
CARRIER DATA	Financial	Moderate	Low	Moderate	Moderate
	Operating Statistics	Moderate	Low	Moderate	Moderate
	Physical Characteristics	Moderate	Moderate	Moderate	Moderate
	Rates/Tariffs	Low to Moderate	High	Major	High
SHIPPER/ CONSIGNEE ATTRIBUTES	Level of Service	Low	Moderate	Major	High
	Commodity	Low	Moderate	Minor	Low
	Market	Low	Low	Minor	Low
	Shipper	Low	Low	Minor	Low
PHYSICAL AND OPERATING DATA	Facility Location	Very High	Moderate	Minor	Low
	Condition of Plant	High	Low	Moderate	Moderate
	Operating Characteristics	Very High	Moderate	Moderate	Moderate
	Use-Capacity	Very High	High	Minor	Low
	Unit Costs-Operating	Moderate	Moderate	Major	High
	Unit Costs-Capital	Low to Moderate	Moderate	Major	High
DIRECT AND INDIRECT IMPACTS	Noise	Low to Moderate	Low	Minor	Low
	Air Quality	Low to Moderate	Low	Minor	Low
	Water Quality	Low to Moderate	Low	Minor	Low
	Soil Erosion	Low to Moderate	Low	Minor	Low
	Ecologic	Low to Moderate	Low	Minor	Low
	Economic	High	Moderate	Minor	Moderate
	Socio-Political	Moderate	Low	Minor	Low
	Aesthetic-Visual	Moderate	Low	Minor	Low
	Energy Consumption	Low to Moderate	Moderate	Minor	Moderate
	Safety-Related	Moderate	Low	Minor	Low

(6) whether the identified deficiencies can readily be met through proxy measures or state-level data collection activities. An over-all assessment was then made by judging whether the deficiencies were minor, moderate, or major.

The over-all assessments were compared with the frequency that the particular data categories are required in statewide transportation systems planning by both the problems/issues and quantitative methods approaches to determine the criticality of deficiencies to statewide transportation planning needs and unmet data needs. The results are given in Table 11.

The most important unmet data needs were found to be:

1. Commodity flow and traffic flow data.
2. Routing data.
3. Rates/tariffs data.
4. Transport level-of-service data.
5. Unit cost data (capital and operating).

Of these five unmet needs, commodity flow and traffic flow data were found to be by far the most important, as they are basic to (1) demand forecasting, (2) modal choice analysis, (3) network analysis, (4) economic evaluation, and (5) impact estimation. None of the other unmet data needs have such wide applicability.

ALTERNATIVE STRATEGIES AND RECOMMENDATIONS

Strategies to reduce deficiencies and generally to improve the quality of data available to the states differ as a function of the data category and the criticality of the deficiency. The research distinguishes between substantive strategies (relating to improvements to the data *per se*) and institutional strategies (relating to who should do the work). Recommendations given in the following concentrate on the former, however.

Six basic strategies for improving the substantive quality and quantity of available data were identified, as follows:

1. Assemble similar data sets. The on-going work by the USDOT Transportation Systems Center is a good example (at the national level) of how existing commodity and traffic flow data files from different sources can be combined to produce a comprehensive data base. The advantages of this strategy are: (1) the work is institutionalized on a continuing basis; (2) necessary cross-checks are made of commodity production and consumption; (3) competitive files can be assessed, differences identified, and the best data sources chosen; (4) long-standing problems in coding systems and definitions are more likely to be identified and resolved, once and for all; (5) the use of existing data files is maximized; and (6) advanced data base management techniques and computer software systems can be used. Such a data base should be designed with state needs in mind, as well as those of the sponsoring federal agency, and should be made available to states. This same strategy applies to other data sets as well.

2. Publish and disseminate data. Many categories of data, especially those involving unit costs, rates, and emissions, are difficult to assemble because of the uniqueness, fragmentation, and obsolescent characteristics of the data sets. The suggested strategy would be to have a governmental agency or private organization prepare reference materials for state DOT use in much the same way that various routing guides, atlases, "facts and figures," and other similar publications are prepared for shippers. One possibility, discussed in Appendix G, would be a handbook or fact book containing a full set of unit cost data in a form readily usable by state planners. (This concept could be extended equally well to rate and emissions data.) Such a handbook, which would be updated periodically, would fully describe and document the sources of data used and the assumptions made in a form readily understandable to the state planner. Further, it would explain how to adapt the data to different planning applications and how to modify it to reflect local conditions.

3. Working relationship with carriers. Under this strategy, states would establish close working relationships with carriers operating within their border by bringing them into the freight planning process, as well as cooperatively working with and relying on them for data analyses, assessments, etc., much of which could be on a cost-reimbursable basis.

4. Expand sample rates of federal data sets. The usefulness of traffic flow data for state planning (as opposed to national and multi-state regional planning) is severely restricted by the low sample rates, which mandate geographic aggregation of the information obtained for disclosure reasons. The recommended strategy is to increase these sample rates so that enough samples are obtained to provide traffic flow data for at least multi-county planning regions within a state. States should actively encourage federal agencies to improve the quality and extensiveness of existing data sets.

5. States conduct primary surveys. For certain types of physical and operating data, states can best assemble the required data. Although states should basically rely on secondary data for freight transportation systems planning purposes, there are instances where primary surveys are required. These surveys should be designed to collect only the limited, specialized information required, as is done in rail branch line shipper surveys.

6. Expand the U.S. Census of Transportation. The Commodity Survey has the virtue or potential of being the only truly comprehensive approach, provided it is expanded to include agricultural, mineral, and wholesaling sectors (as well as transport level-of-service attributes). The recommended strategy is to expand significantly the coverage, sampling rates, and detail sought on sample shipments and to conduct the survey on a continuous basis. Ideally, data on both physical movements and transport expenditures should be obtained, thus tying together the work of the planner and the economist.

CHAPTER THREE

INTERPRETATION, APPRAISAL, AND APPLICATION

The preceding findings are interpreted and appraised in the light of the freight planning situation as it existed in 1976 in most states and regions, because that situation represents the point of departure from which the results of this research will be applied. The current situation, described in the following, affects the way in which planning is done and, as a result, the data that are required. Accordingly, interpretations are drawn regarding both the "planning" findings of this research and the "data" findings.

THE FREIGHT PLANNING SITUATION

At present, limited state resources are being applied to attack a very broad set of problems, using a variety of methods (some of which are in need of substantial improvement). In many states, the role that state government will play in statewide freight transportation planning is still being worked out. Despite these fundamental problems, freight transportation is a matter of utmost importance to each state, particularly to its economic base.

Perhaps one-half of the states are actively pursuing freight transportation planning. Of these, the typical state might have a staff of between one and eight professionals (more often only one or two) able to devote full time to freight planning. Generally staff work is primarily concentrated on railroads, highway truck transportation, and to a lesser extent on ports and waterways. Some federal funding for rail planning has recently become available under the Regional Rail Reorganization Act of 1973 and the Rail Reorganization and Regulatory Reform Act of 1976. Otherwise, freight transportation planning is largely state supported. Planning is typically concerned with physical facilities and economic or environmental impacts; regulation of rates is most often someone else's responsibility.

In part, this situation is the result of past uncertainty as to the state's appropriate role in freight transportation. Freight has largely been the domain of private enterprise and the Federal government, whereas states are responsible for the intrastate regulation of rates and for some types of safety regulation and inspection, the main actors have been the carriers, USDOT, ICC, CAB, and the Corps of Engineers. As the railroad crisis deepened since 1970, states have become more involved in rail system planning, particularly with light-density lines. Through this, the critical importance of adequate, economical, and efficient freight transportation to the state's economy has become more apparent to state governments. The need for preparing comprehensive plans for multi-mode freight systems has received renewed interest. But the state's role is still being hammered out, and each state may adopt a different policy and approach. What role should the state adopt with regard to private industry? What aspects of planning are properly federal, as opposed to state or local? It may turn out that the appropriate responsibility, even within a mode, is divided: for example, the federal government and the railroads may have primary responsibility for main line railroad planning, whereas the state role is limited to light-density lines. All this is still being debated and consequently will remain unsettled for quite some time.

From the point of view of methodology there is a number of techniques for certain aspects of freight planning, as described in Appendixes B through G. However, there is a great need for improvement of techniques. Moreover, there is no "grand design" for pulling together or coordinating the many separate kinds of planning activities. Previous conceptions of comprehensive, multi-mode planning, such as urban transportation planning, do not appear to work in the freight field. In particular, no satisfactory linkage has been created between economic or development planning and transportation planning.

None of these difficulties, of course, reduces the importance of the subject matter or the need for a constant search for better adaptation in an area of economic, social, energy, and technological change. But they do have strong implications for state planning programs and for the data that such programs will require.

INTERPRETATION OF FINDINGS REGARDING PLANNING

In light of the preceding description of the situation, how should the findings of the research regarding planning be interpreted? The principal findings were (1) that there is a diversity of problems and issues, of possible state roles, and of geographic/jurisdictional levels at which problems occur; (2) that there is a diversity of actual and potential planning responses; and (3) that there is no consensus as to what a comprehensive freight planning process should be or as to the content of a statewide freight transportation plan.

The answer is that the present diversity of planning responses is an undesirable state of affairs and that in the next five to ten years a consensus should be achieved as to a "core" freight planning process, or at least a common program of freight planning activities that will be used by most states.

The research work did not produce any findings as to what a "core" freight planning process might be, as the research was deliberately oriented to data needs rather than techniques. Proposals have been advanced by sources outside of state government in both California and Pennsylvania, but neither has been tested in practice. Consequently, it is only possible to speculate on what such a process might be.

The minimum essential requirement of a "core" freight planning process is that it should provide connecting linkages between most of the specialized types of freight plan-

ning that a state is likely to use—not simply for the sake of connecting them, but to make certain that separate planning operations do not produce inconsistent or false recommendations. Thus, essential linking components will most likely be:

- Short-range (5 to 10 year) aggregate freight demand forecast by county or substate region. The output of this forecast should be in tons of freight shipped and received, by major (2-digit) commodity classification.
- An estimate of the modal split of the preceding demand.
- Physical and capacity characteristics of the freight modes, mapped and tabulated.
- Capital and operating expenditures likely to be made by the freight transportation system, both public and private.
- General estimates of the direct and indirect impacts of freight transportation system operations.

Basically, these linking components permit (1) across-the-board evaluation of the needs of the state's economy for transportation services, and (2) the comparison of efficiency and impacts of proposed changes in the several modes.

The components, by themselves, do not constitute a process. The lack of a process continues to baffle professionals working in the freight field. Thus the conclusion is that extensive work is required by both federal and state governments, to advance the state of the art in freight planning at the state level.

One practical approach for states to take is to enter into freight planning by small steps, tackling a problem here and a problem there as needs arise or are foreseen. Because of the mixture of public and private interests in freight and the fact that freight planning is a new and relatively uncharted activity, it is most probable that a majority of states will adopt this approach. In many ways this is a desirable strategy that will allow planning techniques to mature, as opposed to the high risk of attempting a massive system-wide or multi-mode approach that could fail and/or be excessively time consuming. On the other hand, major advances in planning techniques will be inhibited or frustrated until the supporting data become available. Hence, the major need is one of improving the data resources available to states.

INTERPRETATION OF FINDINGS REGARDING DATA

In capsule form, the principal findings regarding data were that (1) there are substantial secondary data resources available for state transportation planners, (2) many times these data are not in the form or degree of detail needed for state or regional planning, and (3) the most important unmet data needs are in the fields of commodity and traffic flow, routings, rates and tariffs, level of service, and unit costs.

In the light of limited state capabilities and an immature planning process, such findings accentuate the need for increased effort to make it easier for the states to acquire and use data that are in the form and detail required for state or regional planning.

A dominant need, therefore, is not so much to get more data as it is to make present information more accessible or available to states for use in their planning activities. Accessibility in this sense is the total cost of assembling, coordinating, and checking data. Thus:

1. This NCHRP project is a major step in the right direction because it presents, for the first time, a catalogue of available data with specific directions regarding how to obtain such data (User's Manual, *NCHRP Report 178*).
2. There is a significant need to improve the coordination of the existing files, so that states, for example, will not have to deal with separate files on minerals, agricultural products, and manufactured products as they now are required to do.
3. There is a significant need to increase sample rates in several major files so that data can be published, without disclosure, for smaller geographic areas.

These interpretations accentuate the importance of Federal action, because coordination of existing files, the most important of which are federal ones, if done once at the source, will obviate the need for individual coordination efforts at the state level. It would also make the data more usable for federal purposes. State personnel would then be able to concentrate on planning instead of onerous data assembly operations.

Except for special-purpose shipper/consignee surveys, little need is seen for primary data collection by the states themselves.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

The research work undertaken for the project "Freight Data Requirements for Statewide Transportation Systems Planning" has resulted in the production of two major documents—this Research Report containing findings and interpretations, together with technical appendixes, and a User's Manual (*NCHRP Report 178*) containing a catalogue of available data and techniques for collecting primary data.

The conclusions and recommendations given herein are at the policy level and are concerned primarily with improving the supply of data available to the states.

CONCLUSIONS

1. Although there are substantial quantities of secondary data currently available for freight planning, and these data have been catalogued, many of the data sets are insufficiently detailed, especially in terms of geographic detail, for application at the state level. Further, the coordination between data sets is difficult to achieve. From the perspective of limited state planning staffs, the costs and time now required to assemble the necessary materials are excessive. Therefore, it is concluded that substantial effort is needed to improve existing data sets to make them more useful to the states.

2. States need to collect only a limited amount of primary data to supplement existing data series. The shippers survey is probably the most important type of such primary data collection.

3. There are many separate planning techniques available to address the many varieties of freight problems/issues facing the states. However, (a) the techniques themselves need further improvement and (b) there is a need for a core process to link the various techniques together. The need for improvement on both fronts is important to the states but will be difficult to attain unaided because of limited funds and professional resources.

RECOMMENDATIONS

Given the preceding policy conclusions, the following implementation recommendations are made:

1. The primary initiative for improving freight data must come from the federal government, acting in cooperation with the states. The reasons for direct federal government involvement are (a) most data series are already federal, (b) most freight data need to be obtained nationwide (states, even when planning just for their areas, need data for regions beyond their borders), and (c) the costly, technical nature of data collection and processing.

2. The states should not enter the freight data collection business except (a) for specialized surveys of particular activities (such as shipper/consignee surveys connected with branch line abandonment) and (b) for the assembly of specialized information from secondary sources, such as compiling of physical inventories of freight networks and terminals, and calculation of their capacities.

3. Major federal initiatives in improving freight data should be: (a) to assemble and combine existing data sets so as to facilitate their use; (b) to publish and disseminate those types of data (such as unit costs, rates, energy requirements, and emission rates) which are difficult to assemble because of their unique character, fragmentation, and variability through time; and (c) to expand sample rates of federal data sets so as to provide disclosable information for smaller geographic areas.

4. Improved working relationships should be established between government and private carriers because so many data originate with private carriers.

5. Research into improved planning techniques of several types is warranted, particularly into (a) methods for calculating the costs and revenues, from available data, to be used in economic evaluation techniques, and (b) methods of forecasting future freight demand at the county or multi-county level.

6. Research is needed into the development of a core process by which multiple planning methods can be linked or related in ways that will assure consistent results toward the achievement of state goals.

7. The advent of electronic communications between large shippers and carriers, which is on the horizon, will ultimately change the entire nature of carrier record-keeping systems. Collection of traffic flow data should be incorporated into the development of such systems at the outset. In the meantime, present obsolete systems for providing traffic flow data should be revised to permit mechanical sampling/data extraction or provision of the entire file. Although mechanization can never reach 100 percent, it ultimately could provide the great bulk of traffic flow data.

APPENDIX A

FREIGHT DATA REQUIREMENTS FOR STATEWIDE TRANSPORTATION SYSTEMS PLANNING

This appendix records the results of the initial approach of Project 8-17, which was to deduce data needs for statewide freight systems planning by first identifying the major issues and problems facing representative state departments of transportation. Then probable state roles in addressing the issues/problems were examined, together with the major planning activities that would logically be carried out at the state level to solve the issues/problems. This led, in turn, to a listing of the major classes of data required by states.

It should be noted that the data needs identified through the preceding "top-down" approach have been combined with data needs as identified in Appendixes B through F "bottom-up" approach to provide an over-all ranking of data needs, as given in this appendix.

ISSUES AND PROBLEMS

Survey Procedure

Issue identification started with a series of interviews with public agencies, private companies, and universities undertaking various forms of freight transportation planning. The purpose of these interviews was primarily to identify specific procedures that have actually been used to develop plans, priorities, and capital or operating subsidy programs for freight transportation, and secondarily to rank freight transportation issues and planning needs. During the course of the interviews it became apparent that substantially less quantitative work had in fact been accomplished by state transportation agencies than originally thought; thus not many freight planning procedures and associated data requirements were discovered through the interview process. On the other hand, the interviews did produce a thorough discussion of current problems facing the selected states, indicating what issues were important to states interested in freight planning.

During September 1975 interviews were held with DOT planning staff personnel in California, Connecticut, Iowa, Maryland, and Wisconsin. These states were selected on the basis of (a) existing legislative authority supporting statewide transportation planning activities, including freight; (b) preparation (either complete or in progress) of a statewide master plan for transportation; and (3) current state initiatives in undertaking freight planning "on their own." Interviews were also held with officials in USDOT and its modal administrations, other federal departments, and the regulatory agencies.

In discussing freight issues or problems with state respondents, efforts were made to determine their relative importance: Does the particular issue now or will it likely warrant significant state involvement during the next five to ten years? Further questions were asked focusing on whether the issue was (a) receiving significant department attention; (b) considered to be major, minor, nonexistent, or beyond normal department responsibility; (c) a one-time or recurring problem; and (d) of direct interest or concern to state government (as compared with local governments or in a few cases the federal government). If the issue had received significant attention, additional questions were asked concerning (a) whether staff work had been undertaken to resolve the issue, (b) the use of a formal analytical process, (c) a description of any planning tools or methods employed, and (d) the types of data used and their sources. Issue identification initially was by a list supplied by the interviewer; however, time was allowed at the end of each interview for an unstructured discussion of other issues and problems.

The interview results were carefully studied and augmented with similar information on problems and issues obtained from other sources. In the end, a composite listing of 74 major issues having widespread applicability was developed on a modal basis. The identification of 74 issues represents a compromise between a smaller number of more generalized issues versus the increasing unworkability of an expanded list having somewhat improved specificity. Intermodal issues were not singled out separately; rather, they were included with the mode with which they were primarily associated.

Not unexpectedly, the issues vary by mode. Over one-half of the identified issues were associated with rail or motor carrier transport, where the possibilities for state involvement are the strongest. A moderate level of involvement was foreseen in the case of ports and waterways. Public investment in ports, where done, has usually been by local governments; only a few DOTs have had direct responsibility for the maintenance, operation, and promotion of ports (as Maryland has in the Port of Baltimore). With the sole exception of the New York State Barge Canal, waterways have been a federal responsibility. State involvement in air cargo and pipelines was found to be fairly low. Air cargo terminal facilities are usually financed through long-term lease agreements between the carrier and airport owner/operator (usually a local government). Runways, taxiways, aprons, and buildings are basically provided for passenger transport; the cargo function simply represents a supplementary service. Pipeline planning remains the responsibility of private enterprise. In most states, relatively little new transmission pipeline construction is currently being undertaken. However, there is some talk of slurry pipelines.

In addition to listing issues, the interviews disclosed, for each issue: (1) the planning objective, (2) the past level of state involvement, (3) probable future state involvement, and (4) the potential role of statewide transportation systems planning in regard to each issue. These subjects are

of importance to those individuals who are developing statewide work programs, and therefore determine the format in which the interview results have been presented.

Presentation of Results

The results of the preceding investigations are presented in Tables A-1 through A-6, each reporting on a separate freight mode. A verbal format has been used because there is no other way to convey the many ideas that relate to each issue.

It is expected that personnel in state departments of transportation will find this table useful as a checklist against which their own state's problems and issues, planning objectives, and roles can be compared. The tables assume that a state transportation agency has the legal power to undertake freight planning for all modes, although many individual states do not have such broad powers. The tables also assume no major changes in the present balance of roles between federal and state.

Conclusions on Issues and Problems

What conclusions can be drawn from examining the entries contained in the six tables? First, there is a tremendous variety of types of problems with which the states are concerned; these range from systemwide supply questions to the socioeconomic impact of branchline closings. Second, freight planning is invariably a shared or cooperative program with the Federal government and the carriers. Third, little quantitative state-level work has been done to date. Fourth, interest and involvement in the listed issues will vary appreciably as a consequence of the local problems being different from state to state; as a result, freight planning will remain unique from state to state. Finally, unlike other forms of transportation system planning, no responsibility has been uniquely delegated to states; rather, states must develop their ultimate role through genuine interest, professionalism, and willingness to invest, to promote, to solve emerging or long-standing freight issues or problems.

DATA REQUIREMENTS AS IDENTIFIED BY ISSUES

For the purposes of identifying data needs in priority order, and to facilitate use by state personnel, the results of the interviews have been summarized (Tables A-7 through A-12) in relevant categories; they have also been extended to indicate basic data categories needed to respond to each issue. This format will enable statewide freight transportation planners to observe the frequency with which issues in a particular state fall into groups (a) by type of issue, (b) by level or scale, (c) by role, and (d) by type of planning activity helpful in responding to each issue. The basic types of data needed to respond to each issue are then identified.

The user should employ these tables as checklists, to record which issues/problems are important for his state, what planning activities will have to be undertaken, and what the basic data requirements are. To aid in this use, the categories used are discussed in the following.

Categories of Issues/Problems

For convenience, the issues and problems described in Tables A-7 to A-12 have been categorized into six types, as follows:

Intermodal. Problem involves either (1) the interface between different freight modes, or (2) direct competition between modes.

Line haul. Problem involves intercity movement of freight from an origin area (shipper or local terminal) to a destination area (consignee or local terminal). Includes the condition, operation, and/or cost of the physical facilities (roadbed and vehicle) used to perform the movement.

Terminal. Problem involves handling and local transport operations associated with pickup and delivery of freight from the shipper to the terminal or from the terminal to the consignee. Includes the condition, operation, and/or cost of the physical facilities (terminal, vehicle, possibly roadbed) used to perform the movement.

Competition. Problem involves inter-carrier competition, including such aspects as market entry, routes, services, rates, etc.

Infrastructure. Problem involves government and carrier investment in new or rehabilitated transportation facilities (roadbed, terminal, vehicle).

Impacts. Involves direct and indirect impacts resulting from actual or proposed changes to the transport system (services, tariffs, infrastructure, etc.).

Level or Scale

The listed issues or problems affect different geographic areas. Some are national in scope, many are state or multistate, and a few are essentially local. Scale is a major factor in determining which level of government should ultimately be responsible for solving different issues or problems. Once scale has been determined, the role of the state in addressing a particular issue becomes clearer. This is not to suggest that a state need not be interested or concerned with national or local issues because they would logically fall to other levels of government; rather it suggests that the designation of the lead agency normally conforms to the scale of the problem. The fact that an issue or problem is of interest and concern to a state does not necessarily mean that it is appropriate for the state to take the lead in addressing it. In short, states should recognize the need for a realistic division of responsibility of freight planning among the different levels of government; one which does not inhibit state-level initiative or overstep functions assigned to other units of government.

The several different level or scale categories are described in the following (a problem or issue may, of course, be critical at two or more of these levels):

National. Problem affects all states; lead and major planning response must be by federal government with states retaining an active interest in the problem and adopting a supportive role in the conduct of planning activities.

Multi-state. Regional problems that affect two or more contiguous states; lead and response can be either by (a) federal government as described under "National," or

TABLE A-1

ROLE OF STATEWIDE TRANSPORTATION SYSTEMS PLANNING—RAIL

Potential Issue/Problem	Planning Objective(s)	Significant Attention or State Involvement		Potential Role of Statewide Transportation Systems Planning (TSP)	Implementation Responsibility
		Present	Perceived Future		
1. A National or Regional Rail Systems Plan for Trunk Routes	Focus future promotional, regulatory and financial assistance programs on an agreed-to system of interstate trunk routes. Provide a compatible basis for state trunk route rail planning.	None except for comparable work done by FRA and USRA in the northeast/midwest.	Increasingly important. Lack of a designated national system of rail trunk routes inhibits federal/state programs supporting the use of or improvement of interstate trunk routes. Regional or national plan desirable as framework for state plans.	Implicit federal responsibility, but one which should rely heavily on RR mgt., and state DOT inputs; plan should be developed cooperatively between federal and state governments. Has physical, operational, regulatory and financial components. National rail plan has not been attempted in recent decades; lead must be taken by USDOT and the ICC. State TSP (state DOT working closely with the state regulatory agency) might undertake a physical/condition usage inventory of trunk routes, trunk route functional classification, economic assessments of the impact of rail service changes upon industries utilizing rail service, identification of realignment, by-pass, or route consolidation projects offereing major time or operating cost savings etc. State product would include (1) data, (2) economic assessments, (3) capital project identification and assessments, (4) joint usage and other consolidation proposals, (5) identification of high/wide routes and the location of industries periodically making out-sized shipments, etc. Federal product would be a physical plan of major interstate trunk routes along with policy, regulatory, safety, and financial recommendations designed to bring the developed plan into existence over a stated time period. General direction, thrust, procedures, etc. must be set by the federal government.	Federal government may require legislation to permit systems planning.
2. Construction of New Rail Lines.	Provide efficient, economical transportation through construction of new rail linkages, where major gains in transport efficiency can be achieved.	Virtually none. (permit approvals generally do not involve state transportation objectives.	Continuation of periodic requirements for construction of new rail lines, especially those providing access to major new mineral deposits, (occurs mainly in western, southern portions of U.S.)	While planning, constructing, and operating a new rail line is the responsibility of RR mgt, there are three major areas of state DOT involvement. The first is to objectively advise energy firms opening up new mineral deposits, on relative costs and impacts of alternate modes of transport. This would require economic and environmental impact assessments. The second is to act as a lead agency in (1) coordinating project planning among interested and affected federal, state, and local agencies, interest groups, etc. and (2) obtaining permits and clearances necessary to project implementation. The third, which applies particularly to new main line routes, is to undertake project feasibility studies, perform preliminary engineering, prepare environmental impact statements, etc. The latter presumes (1) project justification is not purely economic (includes social, environmental benefits) and (2) the necessity for federal/state/railroad investment if the project were to be implemented.	RR mgt. with state DOT assistance in obtaining necessary clearances and permits.
3. Electrification of High Density Rail Lines.	Provide more economical, energy efficient transportation on routes having traffic densities sufficient to warrant electrification.	Virtually none.	Some developing interest. Depends upon the role the federal government ultimately plays in promoting electrification for energy conservation purposes.	While planning, constructing and implementing electrification is the responsibility of RR mgt., state DOTs can act as a lead agency in (1) coordinating project planning among interested and affected federal, state, and local agencies, interest groups, etc. and (2) obtaining necessary permits and clearances. While not state TSP per se, states could act as agents of USDOT in administering federal aid to RRs and construction supervision (assumes federal/state financial participation).	RR mgt. with state DOT assistance in obtaining necessary clearances and permits.
4. Construction of Rail Bypass Routes Around Urban Areas.	Relocate non-grade separated trunk routes from densely built-up, urbanized areas by constructing bypass routes.	Occasional relocation generally in lieu of constructing an extensive number of grade separation structures.	Continuation of present response.	Falls within state TSP. Has physical, traffic, safety and resource allocation components. In the past, has been a portion of statewide highway systems planning (rail line relocation in lieu of grade separation of existing tracks). Potential government involvement arises from traffic, safety, and urban environmental problems. Lead must be taken by state DOTs working in close coordination with RRs, and communities adversely affected by RR presence. Applicable only to situations where (1) numerous grade crossings exist, (2) train speeds are necessarily slow and frequent, (3) serious traffic back-up, congestion occurs at crossings, (4) economic growth, redevelopment inhibited by presence of RR tracks, (5) hazardous materials are likely to be transported, (6) cargo security is a problem, and (7) serious noise, public safety, and school/fire/police access problems exist. TSP involves conducting corridor studies of possible bypass routes; also economic assessments of the benefits and costs of rail bypass routes. Product could recommend bypass route construction; bypass routes must be judged against other highway-rail grade separation/crossing projects.	State DOT and RR jointly. Project planning, design, ROW acquisition construction supervision resp. of state DOT (except for RR force account work). Some states require RR and/or local government financial contributions.
5. Terminal/Yard Replacement, Modernization.	Promote improved terminal efficiency (decreased time and cost), enhance carrier viability thru increased traffic, energy efficiency etc. thru federal/state/railroad investment in replacing/modernizing yards.	Virtually none, unless land is preempted by use for highway purposes. (Some pilot or prototype at federal and local level.)	Ultimately important. Depends upon the role the federal gov't ultimately plays in promoting greater terminal/yard efficiency and whether such programs include funding and are implemented thru state DOTs.	Best undertaken cooperatively on a multi-state basis. Has physical, locational, operational, and financial components. In past, resp. of RR mgt. with little or no state or federal involvement except for permits, etc. Potential gov't involvement arises from (1) inability of some railroads to undertake expenditures (2) desire to achieve greater industry efficiency, or (3) reuse of land tied up in railroad facilities. Lead should be taken by USDOT, with participation by state DOTs, RR mgt. and labor, to ensure reasonable investment payoff. TSP involves preparing freight forecasts, corridor flows, modal split, network simulation, terminal/yard condition/capacity/needs/costs. Product would identify terminals/yards requiring replacement/expansion/modernization/consolidation and those no longer needed along with priorities, costs, benefits, and impacts on a terminal/yard basis. Project planning resp. of RR mgt. coordinating with regional and local planning agencies. General thrust, direction, investment criteria should be set by federal gov't.	Shared responsibility. RR mgt. with federal/state financial assistance for land, facilities. Possible state or local ownership & leaseback of facility to RRs.

TABLE A-1 (*Continued*)

Potential Issue/Problem	Planning Objective(s)	Significant Attention or State Involvement: Present	Significant Attention or State Involvement: Perceived Future	Potential Role of Statewide Transportation Systems Planning (TSP)	Implementation Responsibility
6. Provide New or Improve Existing Intermodal Transfer Facilities	Promote intermodalism, use of rail for line haul portion of movement, carrier viability thru increased traffic, energy efficiency etc., improve the efficiency of intermodal facility operations thru greater coordination between railroads, motor carriers, and industry and thru federal/state/railroad investment in new or improved intermodal facilities.	Virtually, none. (some at federal level)	Ultimately important. Depends upon role federal government plays in promoting intermodalism and whether such programs include funding and are implemented in part thru state DOTs.	Best undertaken cooperatively on a multi-state basis. Has physical, operational, regulatory, policy, and financial components. In past, resp. of RR mgt. with little or no state or federal involvement except for permits, etc. Potential gov't involvement arises from desire to promote rail usage, intermodalism. Lead must be taken by USDOT, with participation by state DOTs, RR mgt. and labor. TSP involves preparing freight forecasts, corridor flows, service characteristics, modal split, rail network simulation, facility condition/capacity/needs/costs. Product would identify new facilities required or improvements to existing ones, plus service attributes, rate structures, local pickup and delivery systems, and other factors influencing the creation and operation of a system of intermodal facilities. Project planning resp. of RR mgt. coordinating with regional and local planning agencies. General thrust, direction should probably be set by federal gov't.	Shared responsibility RR mgt. with federal/state financial assistance for facilities, equipment, etc. Possible state or local ownership & leaseback of facility to RRs.
7. Poor Ground Access to Freight Yards for Intermodal Services	Take local trucking off city streets to improve environment; improve operating efficiency; reduce costs, energy consumption thru federal/state investment in improving highway connections between yard and expressway system.	Virtually none.	Subsidiary to question of federal/state/railroad investment in intermodal facilities. Relatively easy to implement. Provides tangible evidence of state DOT interest in and promotion of intermodalism.	Portion of statewide highway systems planning. Has physical, traffic, and resource allocation components. In past, largely ignored due to lack of coordination between RRs and state DOTs and the relatively low volumes of truck traffic. Potential gov't involvement arises from service promotion and esire to reduce truck-induced impacts on local street systems. Lead must be taken by state DOTs coordinating with RRs and local interests. Applicable only to major TOFC/COFC facilities, TSP involves preparing forecasts of TOFC/COFC traffic, determining local origins and destinations, estimating associated truck volumes on different portions of local and state highway systems, determining present levels of service, and estimating service improvements from removing yard or terminal related traffic from links experiencing severe congestion (and associated environmental impacts). Product could recommend access road construction (connecting yard/terminal with urban expressway system or possibly special truck highways between major yards and terminals). Should not be judged solely in comparison with other highway projects and existing plans (may not adequately recognize need).	State DOTs (possibly local gov'ts). State DOT resp. for project planning, design, ROW, acquisition, and construction. Federal/state financing; possible local share.
8. Condition of Roadbed, Track Structure on Main Lines.	Eliminate deferred maintenance, improve safety, operating efficiency, carrier viability thru federal/state investment in assisting railroads rehabilitate and upgrade track (tie replacement, rail renewal, etc.). Preservation of the strongest possible system of trunk routes.	Seven states either own or operate railroads or have capital funds available for main line rehabilitation.	Increasingly important. Depends upon the role that the federal gov't plays in encouraging state investment in main line facilities and whether such programs are ultimately implemented thru states (as opposed to the present pattern of direct investment by federal gov't).	Partially dependent upon multi-state rail systems planning. Has physical, operational, policy and financial components. In past, resp. of RR mgt. with little or no state or federal involvement. Potential gov't involvement arises from inability of some railroads to adequately maintain trunk routes. Lead must be taken by USDOT in close coordination with RR mgt. Role of the states depends to a large degree upon emerging policy of federal gov't. Unilateral state TSP and resulting investment in rehabilitation and/or upgrading of major trunk routes is possible and is being done in at least one state. TSP involves determining present condition, needs, costs, benefits, and priorities for rehabilitation. Project planning resp. of RR mgt. coordinating with state and local agencies. General thrust, direction should be set by federal gov't.	RR mgt. Where states are providing capital funding, project programming should be done jointly RRs carry out rehab projects on a force-account basis.
9. Condition of Roadbed, Track Structure on Light-Density Lines.	Eliminate deferred maintenance, improve safety, operating efficiency, line viability either thru federal/state investment in rehabilitating track or thru operating subsidies to ensure continued service, including necessary maintenance.	Limited to several states. Receiving high attention in northeast, parts of middle west.	Ultimately will become a nationwide concern. Recent federal legislation has extended RRR Act rail service continuation subsidy provisions to non-bankrupt RRs and states outside of northeast/midwest. Otherwise limited state involvement.	Falls within state TSP. Has physical, policy, and financial components. State rail plan requirement in RRR Act necessitates state level planning for branch lines not included in the ConRail system. State rail planning required in northeast/midwest states, optional elsewhere. Applies only to unprofitable lines operated by bankrupts in reorganization under the act. All other branch lines remain the resp. of RR mgt. with little or no state or federal involvement. Contents of state rail plan specified in FRA's "Procedures and Requirements Regarding Applications for and Disbursement of Rail Service Continuation Assistance." TSP involves determining (1) the specific services which should be continued as a function of goals and supporting criteria, (2) the order or funding priority, and (3) the amount and form of financial assistance required. Product is a report (plan) to be submitted to and approved by the FRA administrator. Project planning and implementation remains the responsibility of RR mgt.	RR mgt. Where states are providing capital funding, project programming should be done jointly RRs carry out projects on a force account basis. Where states are providing operating subsidies, maintenance remains resp. of RR mgt.
10. Freight Car Supply, Condition	Reduce/eliminate recurring freight car shortages, cars in poor condition, etc. thru stepped-up car replacement programs by carriers (stimulated by tax credits, per diem charge changes, etc.)	Varies. Little or no interest in car supply problems in east. Western states far more concerned with car supply for movement of farm produce (grain, vegetables, etc.)	Anticipate a growing interest particularly if freight car shortages persist and adversely affect a state's ability to transport its farm products to markets or inhibit development of new energy sources.	Federal responsibility, but dependent upon state inputs. States have a promotional role; must develop knowledge and understanding of car supply problems, causes, potential solutions; should monitor car availability and condition on a continuing basis. Car supply effects level and quality of service. States may elect to develop service standards as a part of state TSP, develop programs to spot check or monitor the actual service provided by RRs (the latter thru state PUCs or PSCs). If service is deficient, states should seek corrective action by the ICC to increase car supply.	Traditional resp. of state public service commissions. State DOTs can significantly aid regulatory agency administrative actions by technical studies, shipper surveys, periodic monitoring of car supply problems (if not done by state regulatory agency).
11. Excess Physical Plant, Land Utilized for Rail	Recycle redundant, underutilized land into more productive urban use thru facility consolidation/modernization by railroads and land redevelopment by local planning and urban renewal agencies.	Virtually none outside RR industry (sole source of scarce capital). Limited recognition of what constitutes excess physical plant and possibilities for consolidation of yards and terminals.	Once state/RRs agree on what constitutes excess physical plant, states will become interested in the orderly disposal or land banking of land not required for rail transportation purposes.	Falls within state TSP. Has physical, policy, and financial components. In past, responsibility of railroad management with little or no state or federal involvement. Lead can be taken by states in cooperation with railroads and local planning agencies. TSP involves a operational analysis of present facilities, estimation of their future utilization, and identification of capital investments and operating changes necessary to permit phasing out of underutilized facilities. Identification of excess facilities usually straightforward: implementation of change must recognize railroad desire to obtain fair profits from land resource plus raising capital to shift or consolidate facilities elsewhere. Joint financing between railroads and state and local governments possible, but rarely done.	Shared resp. between RR mgt. and local gov't. Initiative should come from local gov't.

Potential Issue/Problem	Planning Objective(s)	Significant Attention or State Involvement		Potential Role of Statewide Transportation Systems Planning (TSP)	Implementation Responsibility
		Present	Perceived Future		
12. Termination of Service	Arrange for the continuation of service on non-viable lines where the local economy would be adversely affected thru use of federal/state subsidies or negotiated solutions between government, shippers, labor, and affected railroads. Where service is not required, to provide for alternate common carrier or private service, if necessary, and the orderly withdrawal of rail service.	High degree of attention in northeast and parts of middle west. Developing capability to prepare quantitative analyses of impacts of branch line abandonment.	Increasing sophistication and standardization of analytical procedures. Capability developed in states outside of northeast, midwest. Improved decision-making.	Falls within state TSP. Has policy, economic, service, and financial components. State rail planning required in northeast/midwest states, optional elsewhere. RRR Act mandates detailed state-level planning for branch lines not included in the ConRail system, if states desire to participate in rail services continuation subsidy program. Applies only to unprofitable lines operating by bankrupt carriers in reorganization under the Act. All other branch lines remain the responsibility of railroad management with normal federal regulatory involvement. Contents of state rail plan specified in FRA's "Procedures and and Requirements Regarding Applications for Disbursement of Rail Service Continuation Assistance." TSP involves determining (1) the specific services which should be continued as a function of goals and supporting criteria, (2) the order of funding priority, and (3) the amount and form of financial assistance required. Product is a report (plan) to be submitted to and approved by the FRA Administrator for lines failing under RRR Act: also a plan describing the service, anticipated patronage and costs, expected future, and conditions underlying state support for continuation of service on other light density rail lines within state. The latter should include criteria for branch line retention and subsidation or cost sharing, service standards, track maintenance standards, etc. to place retention/termination decision on an objective basis. Planning for light-density lines not included in the above would normally follow the same techical pattern (or some lesser version thereof).	Shared resp. between RR mgt. and state DOTs. State DOTs must take lead in developing possible solutions, negotiating terms among RR mgt., local governments, shippers.
13. Disposal of Right-of-Way of Abandoned Light-Density Lines	Preserve RR ROWs no longer required for railroad purposes for other transportation or for recreationally-oriented purposes.	A number of states have legislation granting DOTs the right of first refusal in RR disposal of excess ROW. Some DOTs can purchase RR ROWs for highway purposes.	Continuing, perhaps increasing, acquisition of RR ROWs for transportation, utility or recreational purposes. Acquisition potentially constrained by demands on capital funds.	Falls within State TSP. Has physical, policy, and financial components. In past, resp. of RR mgt. with little or no state or federal involvement. Lead should be taken by state DOTs to insure the orderly disposition of RR ROWs no longer needed for rail transportation purposes. TSP would involve first determining whether the ROW was required for transportation purposes and, if not, cooperatively determining (with the state utility commission and parks and recreation agency) its use for utility or recreational purposes. Objective would be to (1) determine its potential and (2) identify the gov't agencies, if any, which may want and havethe funds to acquire the property. Work may involve small scale planning studies to develop a prospectus or proposal for budget approval or federal funding application purposes.	Shared resp. between RR mgt. and state DOT. Latter coordinates with other state agencies if ROW is not needed for transportation purposes.
14. Level/Quality of Service	To insure the provision of frequent, convenient reliable services, both local and line haul. To increase the utilization of rail service by improving service attributes.	Little or no interest in level/quality of service problems (except perhaps by state public service commissions).	Anticipate a growing interest particularly if rail utilization continues to decline or if state economic development is hindered by poor quality rail service.	Falls within state TSP. Has policy, regulatory, operational components. In past, responsibility of railroad management with little or no state or federal involvement. Role of states depends to a large degree upon emerging policy of the federal government. Must be worked out in coordinated fashion with railroad management and labor, federal and state government. TSP involves determining present service levels, determining industry requirements for rail service, establishing a set of guidelines or service standards on a line-by-line basis, and working with railroad management and industry to achieve standards via a monitoring program. Initially will apply to light-density lines supported in part by federal subsidies; ultimately may be extended to other parts of the state rail system.	State DOTs working closely with federal gov't, state regulatory agencies. Latter resp. for corrective actions.
15. Developing, Testing, Marketing New Services to Promote Rail Usage	Promote rail usage thru developing, demonstrating and marketing new, innovative services. Improve carrier viability thru increased traffic, achieve greater energy efficiency, etc.	Virtually none.	Increasingly important. Depends upon whether the federal gov't encourages state promotional activity (compared with assuming full responsibility for this.)	While primarily the resp. of RR mgt., there is appreciable room for state initiative (and federal), provided that states are willing to invest in demonstration-type projects. Depends upon the acceptance of an advocacy role for state government and a willingness to support the testing and demonstration of new concepts in concert with RR mgt. and labor. TSP may involve identifying potential projects, preparing prospectus, securing funding, implementing the project, determining results, and if successful, instituting long-term changes. Appreciable opportunity may exist in testing different service concepts on light-density lines. States should assist RR mgt. by understanding and endorsing the need for innovation, examining the results, and supporting resulting projects and programs which are in the overall public interest.	RR mgt. State DOTs should actively promote and support innovation, both directly and thru encouraging federal activity. RRs need to keep DOTs apprised of such activity.
16. Rates (inequitable, inconsistent, inflexible to changing traffic, non-compensatory, revenue divisions between railroads, etc.)	Promote a restructuring of rates and other regulatory controls to allow carriers the largest possible competitive freedom to meet the challenge of private and unregulated carriers thru relaxation of certain specific rate and service restrictions.	Virtually none, apart from efforts by state public service commissions to hold rates down.	Increasingly important. States will become increasingly involved in promoting rate and service changes before federal regulatory bodies, as well as applying these concepts to intrastate movements.	Basically, resp. of federal gov't, rather than states. States do have a legitimate concern in achieving an economically sound private railroad industry maximizing its market share in freer competition with other modes. States have a direct interest in rates, divisions, surcharges, etc. as they apply to both main line and light-density service. States have a promotional role in encouraging federal activity in restructuring rates and other regulatory controls. States have the opportunity to test out deregulatory principles on intrastate movements, some of which represent substantial freight movements. Responsibility of regulatory agencies rather than state DOTs, although close coordination is desirable.	Federal and state regulatory agencies working with RR mgt. State DOTs should work closely and cooperatively with federal and state regulatory agencies.
17. Taxation of Roadbed, Facilities.	Relieve the burden placed on railroads, but not the other modes, by alleviating local taxation of railroad property and other forms of taxation applied at the state level.	Possibly a half dozen states have enacted some form of tax relief. Supreme Court has ruled that only states can provide relief.	Increasingly important. States will become increasingly involved in eliminating the grosser inequities involving taxation of railroad property.	Depends upon federal policy and state legislation to eliminate taxation of railroad properties at rates or on bases other than those that apply to industrial property or to competing modes. Basic policy, direction, leadership, must come from the federal gov't. Objective is to establish uniform policies/principles underlying taxation of rail property. States would normally implement tax relief or phase out programs through legislation of their own. TSP might include estimates of the amount and impact of present taxation policies upon the railroad industry in that state.	Within state gov't, generally legislative committees, gov. office, budget personnel. State DOTs can assist via impact studies.
18. Inability to Raise Necessary Capital for New Investment, Rehabilitation.	Eliminate deferred maintenance, improve safety, operating efficiency, carrier viability thru supporting private investment in rehabilitating and upgrading track and other facilities via low interest loans, loan guarantees, grants, etc.	Virtually none. (except Pennsylvania, Iowa, Illinois, Vermont)	Anticipate a growing interest in ensuring adequate financing of necessary rail plant rehabilitation requirements. Little initiative likely at state level, however, without federal gov't involvement.	Best undertaken cooperatively between RR mgt., federal and state gov'ts. States do have a legitimate concern that required capital is raised and investments are made equitably among the states. TSP may consider new funding mechanisms such as state investment, cooperative arrangements between RR mgt. and government, the use of loan guarantees and the use of surcharges, trust funds, etc. for direct revenues or for capitalization purposes. Also included within state TSP is easing existing legal constraints which would prevent state gov't capital investment in privately owned and operated facilities.	Shared responsibility RR mgt. with federal/state gov'ts.

TABLE A-1 (*Continued*)

Potential Issue/Problem	Objective(s)	Significant Attention or State Involvement: Present	Significant Attention or State Involvement: Perceived Future	Potential Role of Statewide Transportation Systems Planning (TSP)	Implementation Responsibility
19. Merger of Competing or Complementary Railroads.	Improve carrier viability	Yes, when merger proposals are made.	Anticipate a growing interest in performing detailed analyses of potential effects and impacts of merger proposals as a backup to testimony of state officials.	Direct resp. of federal gov't, although of great interest to states. Control over management and financial arrangements resp. of federal regulatory agencies. Issue does not fit well within usual framework for state TSP; tends to be a non-recurring phenomena having unique characteristics. Hence mergers inevitably necessitate special studies which can utilize products from a TSP program as a basis for determining resulting impacts upon the state and whether such a merger fits within or contributes to the goals and objectives established by TSP.	RR mgt.
20. Substituting Railroad Motor Carrier Pick-up/Delivery Service-TOFC/COFC in lieu of Light-Density Rail Service.	Improve carrier viability, ability to respond to changing markets, abandonment of light density lines while providing present users with continued railroad-provided service.	Virtually none.	Anticipate a growing interest in positive single-carrier solutions to service continuation in the event of light-density line abandonments.	Falls within state TSP. Has policy, economic, service, regulatory and financial components. In past, not possible to achieve on account of legal constraints. TSP involves analyzing the economics of potential railroad-provided motor carrier service to determine when and where such substitution could be profitably undertaken, and whether this course of action represents a viable alternative to outright abandonment or subsidation. Product would indicate which light-density lines, if any, might be best operated under service substitution arrangements.	RR mgt., working closely with state DOTs and users of rail service.
21. Environmental Impact of Railroad Facilities	Protect and enhance the physical environment, especially air quality, noise, and water.	Some, especially in relation to light density lines. Findings generally show low levels of impact.	Moderate increase especially in comparison with other modes. Environmental impact of railroads by themselves is not an issue at a state level.	Falls within state TSP, even though NEPA is a federal requirement (a few states do have state equivalents of NEPA). Has direct policy and investment implications; indirect aspects through environmental assessments of proposed investment programs or economic/regulatory policies, particularly in terms of impacts upon air quality, urban noise, water quality, and other potential changes to the physical environment. Product may be an environmental impact statement or simply an environmental report or assessment accompanying a state plan. Federal agencies resp. for preparing environmental impact statement for programs initiated at that level.	RR mgt. working closely with state environmental protection agency.
22. Socio-Economic Impact of Railroad Facilities	Protect and enhance the quality of the human environment, especially the local economy.	Some, especially in relation to light-density lines. Great concern over employment losses from rail line abandonment.	Continued attention to employment and personal income effects of rail line abandonment.	Falls within state TSP, particularly in contributing to state economic goals relating to employment and income growth. TSP may involve preparing before/after economic assessments of proposed investment programs or regulatory policies, particularly with respect to continued operation of existing industries and attraction of new commerce. Product may be a separate assessment of the economic effects of implementing a state rail plan or this may be included with environmental impact assessments. Appreciable attention has been given to the economic effects of local rail service termination.	State DOTs working with local gov'ts.
23. Energy Consumption	Reduce the amount of energy used for transportation purposes, increase efficiency.	Some, especially in relation to light-density lines. Findings mixed-generally show low levels of impact.	Increasingly important. Depends to a large extent on the emphasis placed by federal government in promoting energy efficient mode utilization. Energy consumption of railroads by themselves not an issue at the statewide level.	Falls within state TSP, although heavily depending upon federal government policy. Also has operational and regulatory components. Unilateral state action for energy conservation reasons is possible but unlikely until general thrust, direction is set by federal government. TSP involves determining energy consumption on a system basis and then determining the effects of different policy or regulatory alternatives on energy consumption and existing transportation services. Usually involves intermodal comparisons. Product would be consumption estimates related to present or future travel patterns and hypothesized policies or restrictions, which may be included in a plan document. Potentially one of the most important areas for state DOT involvement.	Federal gov't, with state DOT inputs.
24. Safety (derailments, hazardous materials, etc.)	Protect the public from accidents stemming from roadbed or equipment failure or condition.	Some states are involved in roadbed, locomotive, and freight car inspection programs through public service commissions.	Increasing attention.	Resp. of states as well as federal gov't. Resp. may be assigned to state public service commission or DOT, depending upon legislation forming DOT. Primarily a regulatory problem, rather than state TSP. Safety standards, regulations for track, locomotives, and freight cars have been set by federal gov't; efforts at state level primarily inspection and enforcement. Hazardous materials transport resp. of federal gov't.	Shared responsibility between federal gov't, states, and railroads.
25. Safety at Railroad-Highway Grade Crossings	Increase emphasis on better and more widespread protection at rail-highway grade crossings, particularly the more heavily used trunk routes where train speeds are high.	On-going programs to grade-separate high volume crossings, upgrade protection devices at other crossings.	Continuation of present attention and involvement. Possible changes in funding arrangements between federal/state governments and railroads.	Falls within state TSP, portion of statewide highway systems planning. Has physical, accident traffic and resource allocation components. Lead must be taken by state DOTs, coordinating with RRs and local interests. TSP involves preparing traffic estimates, compiling accident records, identifying potential projects, estimating costs, obtaining funding, setting priorities for projects on a program basis. Product is an active program for improving the protection offered motorists at grade crossings on a systematic basis. Well established program in most states.	State DOTs working with RR mgt., local communities.

TABLE A-2

ROLE OF STATEWIDE TRANSPORTATION SYSTEMS PLANNING—MOTOR CARRIERS

Potential Issue/Problem	Planning Objective(s)	Significant Attention or State Involvement		Potential Role of Statewide Transportation Systems Planning (TSP	Implementation Responsibility
		Present	Perceived Future		
1. Inadequate Supply of Highway Facilities	Reduce transport time and cost from circuitous routings, gross weight limits, etc. thru bridge replacement, pavement strengthening, and interstate system completion.	A major upgrading of state primary routes, lesser upgrading of secondary routes, more limited upgrading of highways under local jurisdiction (incl. farm-to-market-roads) has taken place in recent years.	Emphasis changing away from capital intensive investments (new highways, reconstruction)to safety improvements, bridge rehabilitation or replacement and highway rehabilitation and preservation.	Portion of statewide highway systems planning. Has physical, condition, traffic, and resource allocation components. In past, little specific planning consideration has been given to the needs of motor carriers separate from person movement via automobile, except where truck traffic seriously affected roadway capacity or operating conditions. Pavement strength, turning radii, and gradient effects of heavy trucks have long been recognized and included in highway designs. Potential gov't involvement arises from desire to reduce truck-induced impacts on state and local systems. Lead must be taken by state DOTs coordinating with motor carriers and local gov'ts. TSP might include designation of intercity truck routes, periodic review of the need for climbing lanes, designation of truck lanes on heavily utilized urban arterials, identification of structures having load weight limits necessitating circuitous routings for expedited reconstruction, etc.	State DOTs working closely with local gov'ts, trucking associations.
2. Highways in Poor Physical Condition	Undertake necessary rehabilitation to eliminate deferred maintenance, safety deficiencies.	See above. In many states, upgrading has eliminated seasonal load restrictions and lessened annual maintenance needs.	See above. Varies from state-to-state. In some states, may require increase in capital resources allocated to maintenance and rehabilitation.	Highway maintenance responsibility of state and local governments. Not generally considered part of TSP, except perhaps for inventorying conditions and assigning priorities associated with facility rehabilitation.	State DOTs.
3. Traffic Congestion (particularly in urban areas)	Reduce congestion to reduce time and cost of truck pickup and delivery operations, particularly in large urban areas thru government investment and other programs to improve the efficiency of urban goods movement (UGM).	Construction of urban expressways and arterials, TOPICS improvements to existing arterials, traffic engineering improvements.	Continuation of past programs. Increased study of urban goods movements in larger, most congested urbans. Projects demonstrating feasibility of route and temporal consolidation of pickup and delivery operations.	Falls within state TSP for facilities in rural areas, part of the joint state-local UTP process in metropolitan areas having central city populations greater than 50,000. Has physical, policy, traffic and resource allocation components. In past, truck congestion considered indirectly. Rising interest in UGM, limited practical applications to date. Issue largely confined to CBDs of largest, densest urban areas. Potential solutions vary from capital intensive (new arterials, off-street loading, etc.) to management and institutional solutions. No direct involvement other than financial envisioned for state TSP.	State DOTs and local gov'ts implementing recommendations from UTP process.
4. Temporal Restrictions on Highway Usage	Reduce truck usage of selected highways during rush hours (urban arterials, expressways) or during peak periods of weekend/vacation travel to reduce congestion, improve operating conditions.	Some, generally thru state regulatory agency imposed restrictions on intercity travel.	Gradually increasing restrictions on truck travel during particular hours or the weekday in urban areas, generally related to specific areas, routes, or facilities.	Part of the UTP process. Has policy, traffic, economic components. Can be considered a part of UGM. Issue largely confined to specific facilities experiencing high congestion. Spillover effects on local arterials and resulting impacts must also be considered. Economic effects of temporal restrictions on motor carrier industry part of state TSP, also modal diversionary effects of such regulations.	State DOTs and/or local gov'ts (depends upon who has operating and maintenance responsibility for particular facility.)
5. Regulations Pertaining to Maximum Permitted Vehicle Weights and Dimensions	Increase the efficiency of motor carriage while preventing overloading of pavements, adverse safety impacts on other vehicles, uniformity among states to reduce transport costs to motor carriers.	Reaction to industry-promoted changes to maximum permitted vehicle weights and dimensions. Issue arises periodically in different states.	Continuation of past.	Partially dependent upon multi-state or national legislation pertaining to maximum vehicle weights or dimensions. Has policy, physical, maintenance, and operational components to states, economic and efficiency aspects to carriers. Lead can be taken by state DOTs in quantitatively assessing the impact that increased weights or dimensions would have upon traffic flow, safety, and maintenance costs of state and local systems and economic benefits accruing to motor carriers and users as a result of more efficient and economical trucking operations. Such assessments would tend to be special purpose studies reacting to external initiatives. Where the issue is conformity with neighboring states, such studies fall within state TSP; otherwise, it tends to be multi-state or national in scope. The federal gov't should take the lead in the latter case.	State DOTs working with legislative committees.
6. Terminal Relocation, Consolidation	Promote improved transport efficiency, lessen intramodal and intermodal transfer costs, enhance carrier viability through greater terminal efficiency, lower costs for users, energy efficiency, thru federal/state/local/motor carrier investment in relocating/consolidating terminal facilities.	Virtually none. (Some at federal and local level)	Ultimately important. Depends upon the role the federal gov't ultimately plays in promoting greater terminal efficiency and whether such programs are implemented in part thru state DOTs.	Falls within state TSP in close coordination with transportation planning in metropolitan areas. Has physical, operational, economic, energy consumption, and financial components. In past, resp. of motor carrier mgt. with no gov't involvement other than for building permits, land use compatibility, etc. Potential gov't involvement arises from (1) desire to achieve greater industry efficiency particularly on local pickup/delivery operations, (2) congestion on city streets from trucks traveling to/from poorly located terminals, and (3) land use conflicts and adverse impacts upon the environment from trucking activities. TSP involves preparing freight forecasts, corridor flows, modal split, network simulation, terminal requirements/costs. Product would identify those terminals which lend to relocation/consolidation. Project planning resp. of local officials working directly with motor carrier mgt. General thrust, direction should be set by state or federal gov't.	Motor carriers working closely with local gov'ts. In some cases, state/local financial assistance may be required to acquire/construct terminals and consolidate operations (with regulatory agency approval.)
7. Cargo Security	Reduce the incidence of cargo theft and thereby reduce transport costs to user.	Some at the local level in large metropolitan areas.	Increasing interest from law enforcement officials, insurance companies, motor carriers.	Falls outside of state TSP although the economic impact of cargo security programs in reducing loss and damage claims is of interest with respect to rates.	Local gov'ts.

TABLE A-2 (*Continued*)

Potential Issue/Problem	Planning Objective(s)	Significant Attention or State Involvement: Present	Significant Attention or State Involvement: Perceived Future	Potential Role of Statewide Transportation Systems Planning (TSP)	Implementation Responsibility
8. Amount of Intramodal Competition	Achieve more economical motor carrier transport services by increasing or limiting competition.	Regulatory agency control over market entry for non-local cartage. Virtually none by state DOTs.	Continuation of past.	Presently the responsibility of federal and state regulatory agencies. While not done on account of the present institutional framework for decision making, state TSP could provide disinterested technical analyses of the economic effects of increased competition on a corridor or area basis. Such studies would involve preparing forecasts, estimating the division of traffic among the carriers and resulting costs, effects on rates, cross-subsidies, estimates of net operating income and other measures to quantitatively judge whether increased or decreased competition would be in the public interest. Product would be individual assessments of the economic effects of increasing or limiting competition in selected areas or corridors.	Federal and state regulatory agencies. State DOTs have a support and/or promotional role.
9. Regulatory Modernization	Promote a restructuring of rates and other regulatory controls to allow carriers the largest possible competitive freedom to meet the challenge of private and unregulated carriers thru relaxation of certain specific rate and service restrictions.	Virtually none.	Increasingly important. State DOTs will become increasingly involved in promoting rate and service changes before federal and state regulatory bodies.	Shared resp. between federal and state gov't. Both levels of gov't have identical objective of achieving an economically sound common carrier motor transport industry -- one able to compete freely with rail as well as private and contract trucking. States have a promotional role in encouraging federal activity in undertaking regulatory modernization for interstate commerce, including such possibilities as rate simplification, deregulation, freer market entry, increased size or elimination of commercial zones, one-way haul restrictions, extending regulation either in part or in full to cover exempt carriers, etc. TSP can support both state promotional efforts with the federal gov't and intrastate regulatory changes through technical analyses of the economic effects of specific rate and service restriction changes. States have the opportunity to implement rate and service restriction changes on intrastate shipments; the latter being the responsibility of regulatory agencies rather than state DOTs (close coordination between the two agencies is desirable.)	Federal and state regulatory agencies. State DOTs have a support and/or promotional role.
10. Indirect Subsidation of Motor Carriers	Eliminate indirect government subsidies of motor carriers, if substantial, thru institution of additional user charges/taxation realistically responding to the heavy truck portion of construction/maintenance costs.	Periodic issue. Studies to date present conflicting results. Little work done by states in recent years.	Continuation of present situation. Depends upon federal gov't efforts to eliminate indirect subsidies. States not likely to act by themselves-no major change foreseen.	Basically, resp. of federal gov't, rather than states. Has policy, economic, financial, and design components. In past, issue has been vigorously debated with conflicting evidence being presented by trade associations, government, and other groups. Cost impacts of heavy trucking on highway systems have been difficult to pin down. Renewed gov't involvement arises from potential desire to eliminate all forms of indirect subsidization and support of one mode versus another. TSP can support state promotional efforts through technical analyses of the cost of heavy trucking upon state and local highway systems and the offsetting revenues received from motor carriers. State DOTs have the opportunity not only to conduct detailed economic studies, but to promote corrective legislation at the state level. Close coordination with state regulatory and taxation agencies required in undertaking above studies.	State DOTs working with legislative committees.
11. Intermodalism	Promote intermodalism, greater use of rail for line haul portion of movement by common and private motor carriers, labor efficiency, energy efficiency, etc. thru removing regulatory and institutional barriers to TOFC/COFC service.	Virtually none.	Increasingly important. Depends upon role federal gov't plays in promoting intermodalism and whether such programs are implemented in part thru state DOTs.	Best undertaken cooperatively on a multi-state basis. Has operational, regulatory, policy, and financial components. In past, resp. of motor carrier mgt. with virtually no federal or state involvement. Potential gov't involvement arises from desire to promote intermodalism, rail usage on line haul portion of movements. Lead must be taken by USDOT, with participation by state DOTs, motor carrier mgt., major shippers, and labor. TSP involves preparing freight forecasts, corridor flow, service characteristics, modal split and highway network simulation (heavy truck flows). Product would identify service attributes, rate structures, local pick-up and delivery systems, and other factors involved in implementing intermodalism on a major scale. General thrust, direction should probably be set by federal gov't.	Shared resp. Motor carrier mgt. with federal, state gov'ts, major shippers, labor.
12. Environmental Impact of Intercity Motor Transport	Protect and enhance the quality of the physical environment, especially air quality, noise, and water.	Appreciable attention in connection with the planning and design of new highways, especially expressways in urban areas.	Continued high interest especially in comparison with railroads. Environmental impact of heavy trucks tends to be a localized issue which at times is of intense importance.	Falls within state TSP, even though NEPA is a federal requirement (a few states do have state equivalents of NEPA). Has direct policy and investment implications; indirect aspects through assessment of alternatives involving other modes. TSP may involve preparing before/after environmental assessments of proposed investment programs or economic/regulatory policies, particularly in terms of impacts upon air quality, urban noise, water quality, and other potential changes to the physical environment. Product may be an environmental impact statement or simply an environmental report or assessment accompanying a state plan. Federal agencies resp. for preparing environmental impact statements for programs initiated at that level.	State DOTs working with local gov'ts.
13. Socio-Economic Impact of Intercity Motor Transport	Protect and enhance the quality of the human environment, especially the local economy.	Some, especially in relation to new expressways.	Continuation of present.	Falls within state TSP, particularly in contributing to state economic goals relating to employment and income growth. TSP may involve preparing before/after economic assessments of proposed highway systems or regulatory policies pertaining to motor carriers.	State DOTs working with local gov'ts.
14. Energy Consumption	Reduce the amount of energy used for transportation purposes, increase efficiency.	Virtually none.	Increasingly important. Depends to a large extent on the emphasis placed by federal gov't in promoting energy efficient mode utilization. Energy consumption by motor carriers is a potential issue at the statewide level.	Falls within state TSP, although heavily dependent upon federal gov't policy. Also has operational and regulatory components. Unilateral state action for energy conservation reasons is possible but unlikely until general thrust, direction is set by federal gov't. TSP involves determining energy consumption on a system basis and then determining the effects of different policy or regulatory alternatives on energy consumption, service, and economic use of other resources. Usually involves intermodal comparisons. Product would be consumption estimates related to present or future travel patterns and hypothesized policies or restrictions, which may be included in a plan document. Potentially one of the most important areas for state DOT involvement.	Federal gov't with state DOT inputs.

Potential Issue/Problem	Planning Objective(s)	Significant Attention or State Involvement		Potential Role of Statewide Transportation Systems Planning (TSP)	Implementation Responsibility
		Present	Perceived Future		
15. Vehicle Safety	Protect the public from accidents stemming from roadbed or equipment failure or condition.	Some states are involved in vehicle inspection programs. All states are involved in making safety improvements to roadway systems.	Increasing attention.	While the resp. of states, is generally assigned to law enforcement or regulatory agencies, implementation of safety improvements to state highways generally falls under traffic engineering, rather than statewide planning. Local jurisdictions responsible for implementing safety improvements to roadways under their jurisdiction.	Shared responsibility between federal gov't, states and motor carriers.
16. Level/Quality of Service and Equitable Competition	To insure the provision of frequent, convenient, reliable services, both by local and long distance carriers. To insure that large long-haul carriers do not squeeze out local firms.	Little or no interest except perhaps by public service commissions if there is a shipper complaint. Little is done if a small carrier complains.	Anticipate a growing interest particularly in areas where rail service is discontinued.	Falls within TSP. Has policy, regulatory and operational components. May require Federal (ICC) action as some of the problem arises when long-haul carriers ignore rural or low-freight areas to pursue traffic elsewhere but do not yield the certificates, thereby preventing another carrier from serving. The local carriers who temporarily fill the gap are always at the mercy of the larger carriers who in slow times elsewhere may start using the certificate authority again and skim off the choice cargoes. TSP involves insuring that service is maintained or another carrier takes over the service.	State DOT's working closely with Federal Government and state regulatory agencies.

(b) a grouping of states directly working together and/or delegating responsibility to a regional group (e.g., New England Regional Commission) to act in their behalf.

State-level. Statewide problem; response normally by state planning or transportation agency and/or public service or utilities commission, possibly with regional and local inputs.

Regional. Substate problem that affects a portion of a state; response can be by (a) state planning or transportation agency and/or public service or utilities commission, and/or (b) regional planning or development agency, transportation authority, or the like.

Localized. Substate problem local in scope and effect; response by local planning or development agency, transportation authority, or the like. State planning or transportation agency may provide technical and planning assistance, coordinate preparation of plans and programs, establish criteria, etc.

State Roles

Each issue/problem has been classified into one or more of the following groups. Multiple roles are possible. Of particular interest is the wide variability of roles observed with mode, with kind, and with level or scale of the problem or issue. In defining a state role, this does not mean that states should immediately seek to become involved in each and every issue or problem where involvement has been indicated. Rather, the role identified represents a desirable state of affairs that can only be achieved through a program of continuing involvement in freight planning.

Supportive. Responsibility basically of federal government; state support through performing subtasks such as providing data, conducting economic analyses, assessing direct and indirect impacts.

Technical study. Covers the full gambit of transportation planning activities: data assembly, forecasting, mode split analysis, network analysis, economic evaluation, and impact estimation done by the state planning or transportation agency on its own initiative.

Promotional. Encouraging carriers or other levels of government to provide identified services and facilities with or without subsidies, tax exemptions, and other forms of "hard" promotion.

Coordinative. Administrative assistance to aid private carriers in expediting government review and approval of plans to implement new services, build new facilities, etc.

Capital investment. State-level investment in constructing new or rehabilitating existing transportation facilities (either publically or privately owned) used for freight purposes.

Other financial support. State-purpose funding of freight transportation services, such as rail branchline subsidies, in support of larger socioeconomic goals.

Types of Planning Activities

Ideally, the identification of major planning activities can best be done by examining past state- and federal-sponsored freight-planning studies to see what methods have been used. However, few examples of such studies actually exist. Therefore a subjective approach, built around several hypo-

TABLE A-3

ROLE OF STATEWIDE TRANSPORTATION SYSTEMS PLANNING—PORTS

Potential Issue/Problem	Planning Objective(s)	Significant Attention or State Involvement		Potential Role of Statewide Transportation Systems Planning (TSP)	Implementation Responsibility
		Present	Perceived Future		
1. A National or Regional Port Development Plan	Focus future promotional and financial assistance programs on an agreed-to system of publicly and privately owned/operated port facilities. Make better use of existing facilities, reduce over-investment, excessive competition.	None. Most ports are owned and operated by local gov'ts, except on Great Lakes where many are private.	Increasingly important. Port needs (especially new offshore deepwater ports) will mandate the preparation of regional or national port development plans to guide such development, as well as the rehabilitation and modernization of existing ports.	Implicit federal responsibility, but one which should rely heavily on port authorities, major shippers including oil companies, and state DOT inputs; plan should be developed cooperatively between federal and state gov'ts. Has physical, operational, policy, environmental, and financial components. A national or regional port plan has not been attempted; lead must be taken by USDOT and the Maritime Administration. General direction and thrust must be set by the federal gov't. State TSP might coordinate authority inputs to such planning including an inventory of port facilities, capital project identification and assessments, traffic projections, economic assessments, etc. Federal product would be a physical plan for existing and proposed major ports (international trade)along with policy, environmental, regulatory, and financial recommendations designed to bring the developed plan into existence.	Federal government may require legislation to permit systems planning.
2. New Port Construction Especially Off-Shore, Deepwater Ports for Supertankers.	Provide efficient economical transportation of imported crude oil and petroleum products, minimize environmental impacts, probability and consequences of oil spills.	Virtually none. (Delaware went to court to prevent such port construction.)	Rapidly becoming a major issue among environmentalists. New port construction inevitable as energy consumption increases. Careful planning is essential if such facilities are to receive public approval and implementation. Depends upon the role of federal gov't in promoting new port construction and whether such programs are implemented in part thru state DOT's.	Dependent upon national or regional port planning. Has physical, operational, policy, environmental and financial components. In past, resp. of local gov't or private companies with little or no state or federal involvement except for permits, etc. Lead must be taken by USDOT and the Maritime Administration, with participation by state DOTs, port authorities, major shippers, state and federal environmental protection agencies, Coast Guard, Corps of Engineers, etc. for the port facility itself. State TSP might involve preparing freight forecasts, corridor flows, modal split, network simulation for motor carrier/rail flows to/from the proposed port facility as well as assessment of the condition/capacity/need and costs of constructing or increasing the capacity of any connections to the rail and highway systems. Product could recommend access road or railroad construction.	Federal gov't with state DOT assistance in planning and implementing necessary ground transportation improvements.
3. Capital Required to Expand; Modernize, or Rehabilitate Existing Publicly-Owned Terminals	Undertake necessary physical improvements to keep general cargo terminals competitive with others in terms of available facilities and services, meet growing shipment volumes, and provide jobs and income to the surrounding area.	Except where directly owned by a state, virtually none.	Gradually expanding state role in financing port modernization and rehabilitation when financing cannot be secured by local agencies. Applies particularly to smaller ports having publicly owned and operated facilities.	Best undertaken cooperatively on a multi-state or national basis. Has physical, geographic, operational, environmental, and financial components. In past, resp. of port management with little or no state or federal involvement except for permits, etc. Potential gov't involvement arises from (1) the potentiality of overbuilding particularly where ports are under competing jurisdictions, (2) the inability of some ports to obtain funds for rehabilitation via the bond markets, and (3) the desire to stimulate area employment and income by increasing the amount of freight handled through the port. Lead should be taken by the federal gov't, with participation by state DOTs, maritime interests, port authorities and regional/local gov't. Unilateral state action inevitable without multi-state or national port planning. Certain TSP methodology, such as forecasts and dividing traffic among competitive ports, can best be done on a multi-state or national basis. TSP might involve assembling port condition/capacity/needs/cost estimates from port authorities along with pricrities, costs, benefits, and impacts of desired expansion or rehabilitation projects. General thrust, direction should be set by federal gov't, rather than left entirely to ports and/or states.	Shared resp. Port mgt. with federal/state financial assistance.
4. Capital Required to Expand, Modernize, or Rehabilitate Existing Railroad-Owned Bulk Terminals	Undertake necessary physical improvements to keep major railroad-owned bulk terminals in operation so as to provide jobs and income to the surrounding area.	Virtually none. (USRA Final System Plan addresses issue.)	Gradually expanding state role in financing port modernization and rehabilitation especially when such financing cannot be done by owning railroads.	Likewise best undertaken cooperatively on a multi-state or national basis. Has physical, geographic, operational and financial components. In past, resp. of railroads with little or no state or federal involvement. Potential gov't involvement arises from (1) inability of some railroads to undertake needed bulk commodity terminal rehabilitation, modernization, or consolidation and (2) the desire to promote terminal usage. TSP might involve assembling terminal condition/capacity/needs/cost estimates from owning railroads along with pricrities, costs, benefits, and impacts of desired expansion, modernization, or rehabilitation projects. General thrust, direction should be set by federal gov't, rather than left entirely to ports and/or states.	Shared resp. RR mgt. with federal/state financial assistance
5. Poor Highway Access to Ports for Intermodal Services	Take local trucking off city streets to improve environment; improve operating efficiency; reduce costs, energy consumption thru federal/state investment in improving highway connections between port and expressway system.	Virtually none. (Except for one state.)	Ultimately important. Subsidiary to question of federal/state investment in intermodal facilities owned and operated by public authorities and/or local governments.	Portion of statewide highway systems planning. Has physical, traffic, and resource allocation components. In past, largely ignored due to lack of coordination between port operating authorities and state DOTs and the relatively low volumes of truck traffic. Potential gov't involvement arises from desire to reduce truck-induced impacts on local street systems. Lead must be taken by state DOTs coordinating with port and local interests. Applicable only to major ports. TSP involves preparing forecasts of maritime traffic, determining origins & destinations, estimating associated truck volumes on different portions of local and state highway systems, determining present levels of service, and estimating service improvements from removing port-related traffic from links experiencing severe congestion (and associated environmental impacts). Product could recommend access road construction. Must be judged against other highway projects and overall needs.	State DOTs (possibly local gov'ts). State DOT resp. for project planning, design, ROW acquisition and construction. Federal/state financing; possible local share.
6. Poor Rail Access or Condition of Yard/Terminal Servicing the Port or Bulk Commodity	Provide improved terminal efficiency thru federal/state/railroad investment in replacing/modernizing yards servicing port or bulk commodity terminals.	Virtually none.	Ultimately important. Depends upon the role the federal gov't. plays in promoting rail yard/terminal upgrading and whether such programs are implemented in part thru state DOT's.	Falls within state TSP. Has physical, operational and financial components. In past, resp. of RR or port authority mgt. with little or no state or federal involvement. Potential gov't involvement arises from (1) inability of some railroads to undertake needed yard rehabilitation, modernization, or consolidation, (2) the desire to promote port or terminal usage, (3) desire to promote rail transport to/from port facilities, and (4) reuse of land tied up in underutilized rail facilities. TSP involves preparing freight forecasts, corridor flows, modal split, rail network simulation, terminal/yard condition/capacity/needs/costs. Product would identify facilities requiring replacement/expansion/modernization/consolidation with priorities, costs, benefits, and economic impacts.	Shared resp. RR mgt. with federal/state/port authority financial assistance.

Potential Issue/Problem	Planning Objective(s)	Significant Attention or State Involvement		Potential Role of Statewide Transportation Systems Planning (TSP)	Implementation Responsibility
		Present	Perceived Future		
7. Maintaining/Improving Channel/Harbor Depth, Navigational Aids, etc.	Maintain and, when desirable, undertake necessary marine improvements to keep the port competitive with others in terms of capability for handling current ship designs and tonnages.	Varies. Increasing attention via promotional route with federal gov't.	Increasing attention, particularly in connection with keeping major ports competitive and finding suitable disposal sites for spoil.	Resp. of federal gov't, rather than states. However, goes hand-in-hand with multi-state or national port planning. Has physical, policy, environmental, and financial components. In past, resp. of port management working directly with the Corps of Engineers. Potential state gov't involvement arises from (1) increasing difficulty in obtaining environmental agency approval to undertake dredging operations necessary to maintain required depths and clearances and (2) the cost of spoil disposal. State TSP and environmental systems planning necessary to (1) agree on the work required over time, (2) the conditions surrounding the work, (3) locating spoil disposal sites, and (4) expediting necessary permits and clearances.	Federal gov't with input from state DOTs, state and federal environmental protection agencies, port authorities, shipping interests.
8. Administrative and Institutional Obstacles to Intermodal Transportation.	To eliminate administrative and institutional obstacles to intermodal transportation thru ports, to translate mechanical benefits into economic savings.	Virtually none. (Federal activity)	Rising interest.	Resp. of federal gov't although states do have a promotional opportunity. State TSP should concentrate on understanding current administrative and institutional problems, possibly undertaking economic assessments as appropriate to demonstrate concern. Current problems include (1) eliminating requirements for customs' officials in some cases to open and inspect containers en route, (2) modifying liability regulations governing different transportation modes, (3) establishing through bills-of-lading for through routes and rates, and (4) reducing tendency for cargo to be decontainerized to take advantage of volume rail rates.	Fed. gov't with inputs from state DOTs, port authorities.
9. Regulatory Modernization	To promote changes in existing rate structures designed to encourage intermodalism, improve operating efficiency, achieve economic savings.	Virtually none.	Rising interest.	Resp. of federal gov't, although states should have an interest and concern. State TSP should concentrate on understanding current rate structures and regulation, promote those changes which would help bring about needed change. Of particular concern is the establishment of single factor rates and centralizing regulatory authority for intermodal freight utilizing port facilities.	Fed. Gov't with inputs from state DOTs, port authorities.
10. Environmental Impact of Port Facilities.	To protect and enhance the physical environment, esp. water quality, wetlands, and harbor and control resources.	Appreciable in connection with dredging, spoil disposal for existing facilities, environmental impact and new deep water ports.	Continuation of present.	Falls within state TSP, even though NEPA is a federal requirement (a few states do have state equivalents of NEPA). Has direct policy and investment implications; indirect aspects through assessment of alternatives involving other locations and modes. TSP may involve preparing before/after environmental assessments of proposed port investment programs upon water quality, wet lands, coastal resources, and other potential changes to the physical environment. Product may be an environmental impact statement or simply an environmental report or assessment for proposed port development.	Shared resp. Port authorities working with state DOTs and local gov'ts.
11. Socio-Economic Impact of Port Development.	To protect and enhance the human environment, especially the local economy.	Some, especially in relation to justifying gov't investment in port rehabilitation/modernization.	Continued attention to area employment and personal income effects of port development	Falls within state TSP, particularly in contributing to state economic goals relating to employment and income growth. TSP may involve preparing before/after economic assessments of proposed port investment programs.	State DOTs working with local gov'ts.
12. Energy Consumption	To reduce energy used for transportation purposes.	Virtually none.	Increasingly important. Depends to large extent on the emphasis placed by federal gov't in promoting energy efficiency.	Basically, resp. of federal gov't, rather than states. Inherently coupled with ground transportation, especially using energy efficient forms of transportation and minimizing total length of haul. Ground transportation falls within state TSP. Unilateral state action for energy conservation reasons is possible but unlikely until general thrust, direction is set by federal gov't. TSP could involve determining ground energy consumption on a system basis and then determining the effects of different policy or regulatory alternatives on energy consumption, service, and economic use of other resources. Product would be consumption estimates related to present or future ground shipment patterns and hypothesized policies or restrictions.	Federal gov't with state DOT inputs.

TABLE A-4

ROLE OF STATEWIDE TRANSPORTATION SYSTEMS PLANNING—INLAND WATERWAYS

Potential Issue/Problem	Planning Objective(s)	Significant Attention or State Involvement: Present	Significant Attention or State Involvement: Perceived Future	Potential Role of Statewide Transportation Systems Planning (TSP)	Implementation Responsibility
1. A National or River Basin Waterways Development Plan	Focus future promotional and federal investment programs on an agreed-to system of publically owned/operated waterways.	Virtually none. Most waterways are owned/operated by the federal gov't. (Exception: NYS Barge Canal)	Increasingly important. Increasing competition for gov't funding plus environmental impacts of waterway development will eventually mandate the preparation of river basin or national waterway development plans.	Federal responsibility, but one which should rely heavily on state inputs (state DOTs if transportation is involved); plan should be developed cooperatively between federal and state gov'ts. Has physical, operational, policy, environmental, and financial components. Previous long-range planning done by the Corps of Engineers on a national or river basin waterways transportation plan must be updated. Lead must be taken by the Corps of Engineers and DSDOT. State TSP might coordinate state inputs to such planning, or simply provide transportation inputs and impacts of waterways construction/upgrading. Federal product should be a physical plan for existing and proposed inland and coastal waterways along with policy, environmental, regulatory, and financial recommendations designed to bring the plan into existence.	Federal gov't with state inputs.
2. New Waterway Construction for Transportation Purposes; System Extensions; Major Upgrading of Existing Waterways.	Provide efficient, economical inland and costal transportation for bulk commodities, minimize environmental impacts.	Virtually none.	Rapidly becoming a major issue and concern among environmentalists. Depends upon the role the federal gov't takes in undertaking new waterways or upgrading existing ones. Increasing state interest and concern.	Partially dependent upon river basin or national waterways planning. Has physical, operational, policy, environmental and financial components. Lead must be taken by the Corps of Engineers and DSDOT, with participation by states. State TSP might involve the assessment of the conditions/capacity/needs and costs of constructing or increasing the capacity of any connections to the rail and highway systems. Product could recommend access road or railroad construction.	Federal gov't with state inputs.
3. Determining Benefits Costs of Multi-Purpose Waterway Construction/ Upgrading.	Determining the capital and operating costs and benefits of different types of waterway projects and equitably dividing these costs and benefits among recreational, flood protection, water supply and transportation purposes.	Virtually none.	Renewed interest in how waterways projects are justified.	Basically, a federal responsibility. Has financial and resource allocation components. Has been responsibility of Corps of Engineers; considerable controversy exists over the benefit-cost method used to justify waterways projects. States have a promotional role in encouraging the development and implementation of uniform evaluation methods which truly reflect the transportation costs and benefits associated with waterways projects.	Federal gov't.
4. Maintaining/Improving Waterway Depth, Navigational Aids, etc.	Maintain and, when desirable, undertake necessary marine improvements to channels, navigation aid.	Varies. Increasing attention via promotional activities with Corps of Engineers.	Increasing attention, particularly with finding suitable land disposal sites for spoil.	Responsibility of federal government, rather than states (except for the Barge Canal in New York). However, goes hand-in-hand with river basin or national waterways planning. Has physical, policy, environmental, and financial components. Potential state government involvement arises from (1) increasing difficulty in obtaining environmental agency approval to undertake dredging operations necessary to maintain channel and (2) the cost of spoil disposal. State TSP and environmental systems planning necessary to (1) agree on the work required over time, (2) the conditions surrounding execution of the work, (3) locating spoil disposal sites, and (4) expediting necessary permits and clearances.	Federal gov't.
5. Extending Regulation to Carriers of Liquid and/or Dry Bulk Commodities.	Place water carrier operators on comparable basis with other modes.	Virtually none.	Rising interest.	Resp. of the federal gov't. States have a promotional role in seeking regulatory extensions or comparable deregulation in other modes. TSP can support such promotional efforts through technical analyses of the economic effects of regulatory controls and potential changes in the modal split and volumes of waterborne freight.	Federal gov't.
6. Indirect Subsidation of Waterway Carriers.	Eliminate indirect government subsidies of waterway operators, if substantial, thru institution of service or user charges on inland waterways to at least cover proportionate costs of maintenance and operation.	Periodic issue. States often support present situation for economic development reasons.	Continuation of present situation. Depends upon federal gov't efforts to eliminate indirect subsidies.	Gov't involvement arises from potential desire to eliminate all forms of indirect subsidation and support of one mode versus another. Basically, responsibility of federal government. States have a promotional role in encouraging fair treatment of the different transport modes offering competitive services. TSP can support these efforts through technical analyses of the economic and modal split effects of user charges on water carriers (and indirectly on railroads) for selected movements.	Federal gov't.
7. Environmental Impact of Carrier Usage of Inland Waterways.	Protect and enhance the physical environment; especially water quality.	Appreciable in connection with dredging, spoil disposal, maintaining dikes.	Continuation of present.	Basically, responsibility of federal government, rather than states. See paragraph 4 above.	Federal gov't.
8. Socio-Economic Impact of Waterway Development.	Protect and enhance the quality of the human environment, especially the local economy.	Appreciable especially in justifying government investment in waterways facilities.	Continued attention to employment and personal income effects of port development.	Falls within state TSP, particularly in contributing to state economic goals. TSP may involve preparing before/after economic assessments of proposed federal waterway investment programs on local/state industry and commerce.	State DOTs.
9. Energy Consumption.	Reduce energy used for transportation purposes.	Virtually none.	Increasingly important. Depends to a large extent on the emphasis placed by federal government in promoting energy efficiency.	Basically, responsibility of federal government, rather than states. TSP could involve determining energy consumption of waterway carriers for particular intra-state movements and then making intermodal comparisons. Product would be consumption estimates related to present or future travel patterns and hypothesized policies or restrictions, which may be included in a plan document. Potentially one of the most important areas for state DOT involvement.	Federal gov't with state DOT inputs.

TABLE A-5

ROLE OF STATEWIDE TRANSPORTATION SYSTEMS PLANNING—AIR CARGO

Potential Issue/Problem	Planning Objective(s)	Significant Attention or State Involvement: Present	Significant Attention or State Involvement: Perceived Future	Potential Role of Statewide Transportation Systems Planning (TSP)	Implementation Responsibility
1. A National or Regional Air Cargo Terminal Plan	Focus future promotional and financial assistance programs on an agreed-to system of air cargo routes and terminals.	None. Air Cargo facilities are generally owned or leased by local gov'ts. Some state ownership, however.	Increasingly important.	Implicit federal responsibility, but one which should rely heavily on state DOTs. Plan should be developed cooperatively between federal and state gov'ts. Has physical, operational, policy, environmental, and financial components. General direction, thrust should be set by federal gov't. State TSP can coordinate airport operator inputs to such planning. Federal product would be a physical plan for proposed air cargo facility development along with policy, regulatory, and financial recommendations designed to bring the plan into existence.	Federal gov't with state, airport operator inputs.
2. Air Cargo Terminal Replacement, Modernization, Expansion.	Promote improved terminal efficiency thru carrier or airport operator investment in replacing, modernizing, or expanding present air cargo terminal facilities.	Virtually none.	Limited attention. Provision of terminal facilities left to airlines and airport operators. Usually self-amortizing; state funding not involved.	Partially dependent upon multi-state air cargo systems planning. Has physical, operational, environmental, policy, and financial components. In past, resp. of airline mgt. and airport operators with little direct federal or state involvement. State TSP might involve preparing freight forecasts, estimating future air cargo requirements, determining land and building needs for air cargo facilities. TSP might also involve the assessment of the conditions/capacity/needs and costs of improving ground connections to the local expressway system. In the largest metropolitan areas, state TSP might involve studying the economic feasibility of a centrally located freight consolidation facility.	Local gov't and airport operators with State DOT inputs.
3. Regulatory Modernization, Administrative & Constitutional Obstacles.	Promote changes in existing rate structures and services offered and eliminate administrative and institutional obstacles to encourage intermodalism, improve operating efficiency, achieve economic savings.	Virtually none. (federal activity)	Rising interest.	Resp. of federal gov't, although states should exhibit a continuing interest and concern. State TSP should concentrate on understanding current rate structures and regulation, promote those changes which would help bring about needed change. Increasing interest in deregulation.	Federal gov't with inputs from state DOTs, airlines.
4. Routes and Services; Market Entry.	Ensure the provisions of frequent, convenient, and reliable air cargo services, both line haul and local pick-up delivery.	Appreciable interest in level/quality of service problems, generally promotional.	Continuation of present.	Falls within state TSP. Has policy, regulatory, operational components. In past, resp. of airline mgt; states have shown direct interest and concern and have promoted the extension of routes and services. TSP involves determining present service levels, industry requirements for air cargo service, economic feasibility of such service, indirect community benefits stemming from improved air cargo service, establishing service standards, and working with airlines and communities to achieve expanded services. May involve promotional activities, support of airline applications to the CAB.	State DOTs working closely with airlines, federal gov't, communities.
5. Cargo Security	Reduce the incidence of cargo theft and thereby reduce transport costs to the user.	None. Appreciable interest and involvement at local levels.	Increasing interest from law enforcement officials, insurance companies, air carriers.	Falls outside of state TSP, although there should be an awareness of cargo security programs in existence at larger air cargo facilities.	Local gov'ts.
6. Environmental Impact of Air Cargo Facilities	Protect and enhance the physical environment; especially air quality, noise and water.	Virtually none (air cargo facilities only).	Continuation of present.	Relatively insignificant portion of larger problem dealing with airport location, operations, and development of land surrounding the airport. Falls within TSP. Has direct policy and investment implications. TSP may involve preparing before/after environmental assessments of proposed air cargo investment programs upon noise, safety, secondary development, and other potential changes to the physical environment. Product may be an environmental impact statement or simply an environmental report or assessment.	Shared resp. airport operators working with state DOTs, local gov'ts.
7. Socio-Economic Impact of Air Cargo Facilities	Protect and enhance the quality of the human environment, especially the local economy.	Some, especially in relation to attracting industries dependent upon air cargo service.	Continuation of present.	Falls within state TSP, particularly in contributing to state economic goals relating to employment and income growth. TSP may involve preparing before/after economic assessments of higher level air cargo service on local/state industry and commerce.	State DOTs working with local gov'ts.
8. Energy Consumption.	Reduce energy used for transportation purposes.	Virtually none (air cargo service).	Increasingly important.	Basically, resp. of federal gov't, rather than states. TSP could involve determining freight-related energy consumption of air cargo carriers for particular intra-state movements and then making intermodal comparisons. Product would be consumption estimates related to present or future movement patterns and hypothesized policies or restrictions, which may be included in a plan document.	State DOTs working with airlines.

TABLE A-6

ROLE OF STATEWIDE TRANSPORTATION SYSTEMS PLANNING—PIPELINES

Potential Issue/Problem	Planning Objective(s)	Significant Attention or State Involvement: Present	Significant Attention or State Involvement: Perceived Future	Potential Role of Statewide Transportation Systems Planning (TSP)	Implementation Responsibility
1. System Capacity, including Additional Pipelines in Existing or New Corridors	Provide necessary capacity for the transport of petroleum products and natural gas.	Virtually none.	Relatively little.	Inter and intra state pipeline systems planning is solely done by pipeline transmission companies. Decisions to construct new pipelines generally requires regulatory agency approval at the federal and state levels. Transportation agencies are typically not involved except where pipelines cross under highways necessitating the issuance of permits. State TSP would become involved were it decided to utilize publically owned rights-of-way, such as interstate highways. The main focus of such planning would be on motorist safety and access for pipeline maintenance purposes.	Federal and State regulatory agencies working with pipeline companies.
2. Extensions Into Presently Unserved Areas.	Provide service to all portions of the state; minimize disruption to highway facilities.	Permits issued for pipelines crossing under highways.	Continuation of present practices.	Primarily the resp. of state regulatory agencies working directly with pipeline companies.	State regulatory agencies working with pipeline companies.
3. Slurry Pipelines	Utilization of special pipelines to transport solids to reduce the cost of transport.	Virtually none.	Increasingly important as pipelines compete for products typically transported by waterway carriers or railroads.	Primarily the resp. of state regulatory agencies working directly with pipeline companies. TSP might involve economic assessments of slurry pipeline construction/operation versus conventional rail or water transportation.	Federal and state regulatory agencies. State DOT inputs.
4. Safety (hazardous materials transport).	Protect the public accidents stemming from pipeline leakage or rupture.	Virtually none except at highway crossings where states inspect work done by pipeline companies for conformance with permit conditions.	Continuation of present practices.	Primarily the responsibility of federal and state regulatory agencies.	Federal and state regulatory agencies.

thetical questions, was utilized. The first question pertained to situations where the state had a technical study role: If I were asked to undertake this study, what major planning activities would be necessary? This was supplemented by informally specifying the major conditions surrounding such a study: (1) reasonable time and staff resources, (2) an in-depth investigation, (3) reliance on existing data sets, (4) an end product providing economic analyses of alternate courses of action along with impact assessments, and (5) fully defensible recommendations. Under this situation the major planning activities could be identified fairly conclusively. The second question pertained to situations where the state was not the lead agency: What types of supporting work might I be called upon to provide, under cooperative arrangements between different levels of government? Several variations of the foregoing situation can also be postulated. However in the end, there is still a high degree of uncertainty over what planning activities are likely. To mitigate some of the resulting uncertainty, two levels of potential involvement were identified; the more basic and essential activities were identified by a solid dot in Tables A-7 to A-12, and the optional activities by a circle. The division between basic and optional also reflects the knowledge of where state freight planning capabilities stand today. The resultant categories of major planning activities are given in the following.

Acquire background information and understanding. An essential starting point is a thorough understanding of the issue or problem and a knowledge of what has been done in the past to solve it.

Demand forecasting. Preparing estimates of either short- or moderate-range demand for freight transportation (long-range forecasting is virtually impossible).

- *Mode split analysis.* Dividing demand between competing intra- and intermodal services based on transport level of service, commodity, market, and shipper attributes.
- *Network analysis.* Using simulation techniques, assigning traffic to links on a network for the purpose of estimating traffic flows, supply/capacity relationships, costs, energy consumption, and the like.
- *Economic evaluation.* Economic effect on carriers and/or government from providing new transportation facilities and/or services.
- *Impact estimation.* Assessment of social, economic, environmental, safety, and energy consumption effects on the state and its regions and localities from the provision of new transportation facilities and services.

Each problem may be approached by one or more planning activity categories. Of particular interest is the wide variability of activity with mode and with role. Defining major planning activities does not mean that states are obligated to undertake the activities so identified. Rather, the activities represent the type of planning work they should consider doing if the particular issue or problem were to become a concern to their state.

Issue Priorities

Each issue or problem has been classified into one of the following groups:

- *Priority I.* Issue or problem has been of high public interest in at least a dozen states during the past several years. High probability of state transportation agency involvement, even by those agencies just starting out in freight planning.
- *Priority II.* Issue or problem is of appreciable concern and interest in one or more states, as demonstrated through staff study efforts. Moderate probability of near-term state transportation agency involvement, especially by the more sophisticated and experienced agencies.
- *Priority III.* Issue or problem has not yet reached the point of serious study by any state transportation agency staff, although there is expressed interest. Some likelihood of future state transportation agency involvement, especially by the more sophisticated and experienced agencies.

Establishment of priorities is a complex business. It involves weighing such considerations as (1) the concerns being expressed by organizations and individuals within the state, (2) systematically equating problems both within and between the different modes, (3) the general level of carrier profitability and viability, and (4) the degree of sophistication and past accomplishments in the state's freight planning program.

The priorities of one state may be significantly different from those of another state. Some of this obviously can be explained on the basis of transport infrastructure and geographic location. For example, virtually all states probably have a latent interest in the rail and motor carrier modes, given the extensiveness of the two systems. On the other hand, deepwater port issues directly affect only 23 states, inland waterways 38 states, air cargo (at medium or large hubs) 36 states. States must develop their own priorities, which will in turn determine their data needs. Each state is unique in this regard; the priorities given in Tables A-7 to A-12 are a composite of freight issues or problems found in all states.

Types of Data

The next step was to identify the major classes of data that would be required to address each issue or problem. The procedure for doing this was straightforward: a rough work plan or prospectus was developed for state involvement in addressing each of the listed issues or problems. Data requirements were then derived from the work plan.

Differences of opinion can exist in deciding what constitutes a data need and what does not. The data needs given in Tables A-7 to A-12 represent one set of judgments; others are possible. In general, however, the results portray a reasonable over-all set of data needs for statewide transportation systems planning.

Two levels of data requirements are shown: essential data are indicated by a solid dot in Tables A-7 to A-12 and optional needs by a circle. The division between essential and optional data reflects differences in depth and comprehensiveness possible in technical studies, depending on the time and resources available for the particular study.

Data requirements have been subdivided into five major groups: traffic flow, carrier, shipper/consignee attributes, physical and operating, and direct and indirect impact data. Each group is discussed separately in the following paragraphs.

Traffic Flow Data

The backbone of freight planning at any level is traffic flow data, which are categorized into production, consumption, and flow data. The last category has been divided into three subgroups to represent total commodity, modal share, and vehicle flows. In some cases international flow data would be analyzed separately from domestic; in other cases there would be substantial interest in the actual routings of vehicles. The categories used are as follows:

- *Commodity production.* Government or trade association assembled or synthesized data from major shippers, giving production statistics on a federal-designated region or multi-state region (high-aggregation), state, or county (low-aggregation) basis.
- *Commodity consumption.* Government or trade association assembled or synthesized data from major consignees, giving consumption statistics on a federal-designated region or multi-state (high-aggregation), state, or county (low-aggregation) basis.
- *Commodity flow.* Government or trade association assembled or synthesized origin-destination data geographically linking production and consumption. Commodity flow data are mode-independent and should exclude in-plant transfers and local shipments.
- *Traffic flow.* Government or carrier/trade association assembled origin-destination data collected on a modal basis, generally region-to-region (high aggregation), state-to-state, or county/place-to-county/place (low aggregation).
- *Vehicle flow.* Generally, government assembled origin-destination data giving the movement of freight vehicles (railroad cars, trucks, barges, etc.) on a modal basis.
- *Import/export.* Segregation of commodity, traffic, or vehicle flow data into domestic and international categories.
- *Routings.* Further detailing of traffic or vehicle flow data to capture actual routings over the physical network.

Carrier Data

Some of the issues and problems require knowledge of the financial condition and operating performance of carriers and the characteristics of their route structure and/or rolling stock. Also needed at times is information on rates and tariffs. The types of such carrier-related data are as follows:

- *Financial statistics.* Includes items relating to the over-all fiscal health of for-hire carriers, including, but not limited to, revenue, expenses, capitalization, depreciation, income, dividends, retained income, taxes, and balance sheet.
- *Operating statistics.* Includes items relating to over-all transportation operations of for-hire carriers, such as

TABLE A-7

DATA REQUIRED FOR RAIL PLANNING

Potential Issue or Problem	Type Issue/Prob.: Intermodal	Line Haul	Terminal	Competition	Infrastructure	Impacts	Level or Scale: National	Multi-State	State-level	Regional	Localized	State DOT Role: Supportive	Technical Study	Promotional	Coordinative	Capital Invest.	Other Financial	Planning Activities: Acquire Info/Und	Forecast: Short	Forecast: Long	Mode Split Anal.	Network Anal.	Economic Anal.	Impact Estimation	Priority Group
National/Regional Rail Systems Plan	●	●		●	●		●					●		●				○				○	○	●	III
Construction New Rail Lines		●			●			●	●				●	●		●		●	○	○	○	○	●	●	II
Electrification of High Density Lines		●			●			●	●				●	●		●		●			○	○	○	●	II
Const. Urban Area Rail Bypass Routes		●			●					●	●		●	●		●		●	●	○	○	○	●	●	I
Terminal/Yard Repl. or modernization			●		●					●	●		●	●		●		●	●	○	○	●	●	○	II
New/Improve Inter-modal Transfer Fac.	●		●	●	●					●	●		●	●		●		○	●	○	○	○	●	○	II
Poor Hwy. Access to Rail Yards: TOFC	●				●						●		●			●		●	○				●	●	II
Roadbed Trk. Cond. on Main Lines		●			●			●	●						●	●		●					●	○	II
Roadbed Trk. Cond. Light-Density Lines		●			●					●	●				●	●		●					●	○	I
Freight Car Supply and Condition		●		●			●					●			●			○	○		○	○	○		III
Excess Phy. Plant/ Land in Rail Yards											●				●							○	○	○	I
Terminate Services Light-Density Lines		●								●	●		●		●		●		○		○	○	●	●	I
ROW Disposal Aband. Light-Density Lines											●				●								○	○	I
Level/Quality of Rail Service								●	●	●				●				○	○		○	○			II
Dev., Test, Market New Rail Services	●			●				●	●	●				●				○	○		○	○	○		III
Rates (non-compen-satory, divisions)	●			●				●	●	●		●	●	●				○			○	○	○		III

Data Required by States for Freight Systems Planning Purposes

Potential Issue or Problem	Traffic Flow: Com. Production	Com. Consumption	Commodity Flow	Traffic Flow	Vehicle Flow	Import/Export	Routings	Carrier: Financial	Operating	Physical Char.	Rates/Tariffs	Attributes: Shipper	Market	Commodity	Level-of-Serv.	Physical/Oper.: Facility Loc.	Plant Condition	Operating Char.	Usage-Capacity	Unit Oper. Costs	Unit Capital Costs	Direct & Indirect Impacts: Noise	Air Quality	Water Quality	Soil Erosion	Ecologic	Economic	Socio-Political	Aesthetic-Visual	Energy Consumption	Safety-Related
National/Regional Rail Systems Plan	○	○	○	●	●	○	●	●	●	●						●	●	●	●								●	○	○	○	○
Construction New Rail Lines	●	○			●		○	●	○	●				●	●	●		●	●	●	●	○	○	○	○	○	●	○	○	●	●
Electrification of High Density Lines				●	●		●	●	○	●						●		●	●	●	●						●		●	●	●
Const. Urban Area Rail Bypass Routes				○	●		○									●		●	●	●	●	●	●	●	●	●	●	●	○	○	●
Terminal/Yard Repl. or modernization				○	●		○									●	●	●	●	●	●			●	●	○	●	○	○		○
New/Improve Inter-modal Transfer Fac.				●	●		○									●		●	●	●	●						○	○	○		
Poor Hwy. Access to Rail Yards: TOFC				○	●					○												○	○				○	○			○
Roadbed Trk. Cond. on Main Lines					●											●	●	●	●	●	●										○
Roadbed Trk. Cond. Light-Density Lines					●											●	●	●	●	●	●										○
Freight Car Supply and Condition								●	●	○	●																				
Excess Phy. Plant/ Land in Rail Yards																●	●		●								○	○	○		
Terminate Services Light-Density Lines				○	○									●	●	●	●	●	●	●	●	○	○				●	○		○	○
ROW Disposal Aband. Light-Density Lines																											○	○	○		
Level/Quality of Rail Service				○	●		●				○			●	●	●	●	●	●	●										●	
Dev., Test, Market New Rail Services	○	○	●		○		○	○	○	○	●	●	●	●	●															●	
Rates (non-compen-satory, divisions)			○	●	●	○	●	●	○	○	●			●	●															●	

Potential Issue or Problem	Type Issue/Prob.: Intermodal	Line Haul	Terminal	Competition	Infrastructure	Impacts	Level or Scale: National	Multi-State	State-level	Regional	Localized	State DOT Role: Supportive	Technical Study	Promotional	Coordinative	Capital Invest.	Other Financial
Taxation of Road-bed & Facilities		●	●						●					●			
Capital: New Investment, Rehabilitation					●		●	●								●	
Merger-Competing & Complementary RRs				●				●						●	●		
Sub Truck PUD for Light-Density Lines [1]		●		●						●	●			●			
Env. Impact of RR Facilities, Serv.						●	●		●		●		●				
Socio-Economic Impact RR Fac, Serv.						●			●		●		●				
Energy Consumption		●				●	●		●				●				
Safety: Derailments Hazardous Mat'ls		●				●			●		●		●				
Safety at RR-Hwy Grade Crossings		●				●			●		●				●	●	

Potential Issue or Problem	Planning Activities: Acquire Info/Und	Forecast: Short	Forecast: Long	Mode Split Anal.	Network Anal.	Economic Anal.	Impact Estimation	Priority Group	Data Required by States for Freight Systems Planning Purposes — Traffic Flow: Com. Production	Com. Consumption	Commodity Flow	Traffic Flow	Vehicle Flow	Import/Export	Routings
Taxation of Road-bed & Facilities						●	○	II							
Capital: New Investment, Rehabilitation	○	○	○	○	○	○		III							
Merger-Competing & Complementary RRs	●	●	○	○	●	●	○	II			○	●	●	○	●
Sub Truck PUD for Light-Density Lines [1]	●	○		○	○	●	○	III					○		○
Env. Impact of RR Facilities, Serv.	○				○	○	●	II				○	●		●
Socio-Economic Impact RR Fac, Serv.		○			○		●	II							
Energy Consumption	○	○	○	○	○	○		II				○	●		●
Safety: Derailments Hazardous Mat'ls		○			○	○	○	II			○	○	●		●
Safety at RR-Hwy Grade Crossings					○	●	●	I					●		

Potential Issue or Problem	Carrier: Financial	Operating	Physical Char.	Rates/Tariffs	Attributes: Shipper	Market	Commodity	Level-of-Serv.	Physical/Oper.: Facility Loc.	Plant Condition	Operating Char.	Usage-Capacity	Unit Oper. Costs	Unit Capital Costs	Direct & Indirect Impacts: Noise	Air Quality	Water Quality	Soil Erosion	Ecologic	Economic	Socio-Political	Aesthetic-Visual	Energy Consumption	Safety-Related
Taxation of Road-bed & Facilities	○								●	●	●	●								○				
Capital: New Investment, Rehabilitation	●								●	●	●	●												
Merger-Competing & Complementary RRs	●	●	●	○					●	●	●	●	●		○	○				●	○			○
Sub Truck PUD for Light-Density Lines [1]				○	●		●		●	●	●	●	●		○	○				○	○		○	○
Env. Impact of RR Facilities, Serv.									●	●	●	●			○	○	○	○	○			●		
Socio-Economic Impact RR Fac, Serv.									●		●	●								●	●	●		
Energy Consumption									●	●	●	●								●			●	○
Safety: Derailments Hazardous Mat'ls									●	●	●	●								○				●
Safety at RR-Hwy Grade Crossings									●	●	●	●												●

1/ PUD: Pick-up and delivery

NOTE: ● Indicates a basic and essential activity that should involve states.

○ Indicates an activity that is optional but where some state involvement may be necessary.

TABLE A-8

DATA REQUIRED FOR MOTOR CARRIER PLANNING

Potential Issue or Problem	Type Issue/Prob.						Level or Scale					State DOT Role						Planning Activities							Priority Group
	Intermodal	Line Haul	Terminal	Competition	Infrastructure	Impacts	National	Multi-State	State-level	Regional	Localized	Supportive	Technical Study	Promotional	Coordinative	Capital Invest.	Other Financial	Acquire Info/Und	Forecast: Short	Forecast: Long	Mode Split Anal.	Network Anal.	Economic Anal.	Impact Estimation	
Inadequate Supply Highway Facilities		●			●				●	●			●			●		●	●	●	○	●	●	●	I
Highways in Poor Physical Condition		●			●				●	●			●			●									I
Traffic Congestion in Urban Areas		●			●						●		●		●	●		●	●	○	○	●	●	●	I
Temporal Restrict on Highway Usage		●				●					●				●			●			○	●	●	●	II
Max. Perm. Vehicle Weights & Dimen.		●			●	●			●				●					●	○		○	●	●	○	I
Terminal Relocation & Consolidation			●		●						●			●	●			●	●	○	○	○	●	○	III
Cargo Security			●								●			●									○		III
Amt. of Intramodal Competition				●			●		●			●		●				○	○	○	○	○	○		III
Regulatory Modernization	●	●		●			●		●			●		●				○	○		○		●		III
Indirect Subsidization Motor Carriers		●			●		●		●			●		●				○			○	○	●		II
Intermodalism	●	●	●				●		●			●		●				○	○	○	○	○	●		II
Env. Impact Intercity Motor Trans.						●	●		●		●		●						○			○	○	●	II
Socio-Economic Impact Motor Trans.						●			●		●		●						○			○		●	II
Energy Consumption		●				●	●		●				●					○	○	○	○	○	○		II
Vehicle Safety						●			●		●		●									○	●	●	I
Level/Quality Serv. Equitable Compet.								●	●	●		●		●				○	○		○	○	○		II

Data Required by States for Freight Systems Planning Purposes

Potential Issue or Problem	Traffic Flow							Carrier				Attributes				Physical/Oper.						Direct & Indirect Impacts									
	Com. Production	Com. Consumption	Commodity Flow	Traffic Flow	Vehicle Flow	Import/Export	Routings	Financial	Operating	Physical Char.	Rates/Tariffs	Shipper	Market	Commodity	Level-of-Serv.	Facility Loc.	Plant Condition	Operating Char.	Usage-Capacity	Unit Oper. Costs	Unit Capital Costs	Noise	Air Quality	Water Quality	Soil Erosion	Ecologic	Economic	Socio-Political	Aesthetic-Visual	Energy Consumption	Safety-Related
Inadequate Supply Highway Facilities					●		○									●	●	●	●	●	●	●	●	●	●	●			●		●
Highways in Poor Physical Condition																●	●	●	●		●										●
Traffic Congestion in Urban Areas					●		○									●		●	●	●	●	●	●				○		●		●
Temporal Restrict on Highway Usage					●		●									●			●	●		●	○				●	●	●		
Max. Perm. Vehicle Weights & Dimen.					●				○	○	○					●		●	●	●	●	●	●				●			○	●
Terminal Relocation & Consolidation	○	○		○	●		●	○	○	○						●	●	●	●	●	●						○	○	○		
Cargo Security					●		○																								
Amt. of Intramodal Competition			○	○	●		●	●	●	●	○					●		●	●								●				
Regulatory Modernization				○				●	●	●	●					●		●	●												
Indirect Subsidization Motor Carriers				○	●		●				●					●	●	●	●	●	●									●	
Intermodalism			○	○	○		○				●	●	●			●		●	●												
Env. Impact Intercity Motor Trans.				○	●		○									●		●	●			●	●	○	○	○			●		
Socio-Economic Impact Motor Trans.																●		●	●								●	●	●		
Energy Consumption				○	●		○									●	●	●	●								○			●	○
Vehicle Safety					○											●	●	●	●												●
Level/Quality Serv. Equitable Compet.			○	●	●		○				○	●	●																		

TABLE A-9

DATA REQUIRED FOR PORT PLANNING

Potential Issue or Problem	Type Issue/Prob.						Level or Scale					State DOT Role						Planning Activities							Priority Group
	Intermodal	Line Haul	Terminal	Competition	Infrastructure	Impacts	National	Multi-State	State-level	Regional	Localized	Supportive	Technical Study	Promotional	Coordinative	Capital Invest.	Other Financial	Acquire Info/Und	Forecast: Short	Forecast: Long	Mode Split Anal.	Network Anal.	Economic Anal.	Impact Estimation	
National/Regional Port Dev. Plan	●		●		●	●	●					●		●				○	○				○	●	III
New Port Const. Offshore/Deepwater			●		●	●		●	●	●	●		●		●			○	○	○	○	○	○	●	III
Capital: Modernize, Rehab. Public Term.			●		●				●	●	●		●		●	●		○	○	○	○	○	○	○	II
Capital: Modernize, Rehab. Private Bulk			●		●		●	●				●		●				○	●		○	○	●	○	III
Poor Hwy. Access to Ports: Intermodal	●				●						●		●		●	●		●			○	○	●	●	II
Poor Rail Access to Ports, Yard Cond.	●				●						●		●		●	●		●			○	○	●	○	II
Maintain/Improve Channel/Harbor		●			●	●	●				●	●						○					○	○	II
Adm. & Inst. Obstacles Intermodalism	●			●			●					●		●				●	○		○	●	●		III
Regulatory Modernization				●			●		●			●		●				○	○		○		●		III
Env. Impact of Port Facilities						●					●		●						○					●	I
Socio-Economic Impact Port Dev.						●					●		●						○					●	II
Energy Consumption						●					●		●					○	○	○		○	●		II

Potential Issue or Problem	Data Required By States for Freight Systems Planning Purposes: Traffic Flow							Carrier				Attributes				Physical/Oper.						Direct & Indirect Impacts									
	Com. Production	Com. Consumption	Commodity Flow	Traffic Flow	Vehicle Flow	Import/Export	Routings	Financial	Operating	Physical Char.	Rates/Tariffs	Shipper	Market	Commodity	Level-of-Serv.	Facility Loc.	Plant Condition	Operating Char.	Usage-Capacity	Unit Oper. Costs	Unit Capital Costs	Noise	Air Quality	Water Quality	Soil Erosion	Ecologic	Economic	Socio-Political	Aesthetic-Visual	Energy Consumption	Safety-Related
National/Regional Port Dev. Plan	○	○	○	●	●	●	○	●	●	●						●	●	●	●					●		○	●	○	○		●
New Port Const. Offshore/Deepwater	●	●	●	●	●		○									●	●	●	●	●	●			●	●	●	●	○	○	○	
Capital: Modernize, Rehab. Public Term.			○	●	●	○	○																	○	○	○	●				
Capital: Modernize, Rehab. Private Bulk			○	●	●	○	○	●	○	●														○	○	○	●				
Poor Hwy. Access to Ports: Intermodal				○	●					○												○	○				○	○			○
Poor Rail Access to Ports, Yard Cond.				○	●			○			○																○	○			
Maintain/Improve Channel/Harbor					●		●									●	●	●	●					●	●	●	●	○			
Adm. & Inst. Obstacles Intermodalism			○	●	●	○	●	○	○	○	●																				
Regulatory Modernization			●	●	○	○	○	●	●	●	●					●		●	●	●											
Env. Impact of Port Facilities				○	●	○										●	●	●	●			○		●		●			○		
Socio-Economic Impact Port Dev.																●		●	●								●	●	○		
Energy Consumption				○	●	○										●	●	●	●								○			●	

NOTE: ● Indicates a basic and essential activity that should involve states.

○ Indicates an activity that is optional but where some state involvement may be necessary.

TABLE A-10

DATA REQUIRED FOR INLAND WATERWAY PLANNING

Potential Issue or Problem	Type Issue/Prob.						Level or Scale					State DOT Role						Planning Activities							Priority Group	Data Required by States for Freight Systems Planning Purposes: Traffic Flow							Carrier				Attributes				Physical/Oper.						Direct & Indirect Impacts									
	Intermodal	Line Haul	Terminal	Competition	Infrastructure	Impacts	National	Multi-State	State-level	Regional	Localized	Supportive	Technical Study	Promotional	Coordinative	Capital Invest.	Other Financial	Acquire Info/Und	Forecast: Short	Forecast: Long	Mode Split Anal.	Network Anal.	Economic Anal.	Impact Estimation		Com. Production	Com. Consumption	Commodity Flow	Traffic Flow	Vehicle Flow	Import/Export	Routings	Financial	Operating	Physical Char.	Rates/Tariffs	Shipper	Market	Commodity	Level-of-Serv.	Facility Loc.	Plant Condition	Operating Char.	Usage-Capacity	Unit Oper. Costs	Unit Capital Costs	Noise	Air Quality	Water Quality	Soil Erosion	Ecologic	Economic	Socio-Political	Aesthetic-Visual	Energy Consumption	Safety-Related
National or River Basin Dev. Plan		●			●	●	●					●		●				○	○	●	●	●	●		III	○	○	○	●	●	●	●	●	●	●						●	●	●	●					●		○	●	○	○		○
New Waterway Const. System Ext, Upgrade		●			●	●		●	●	●	●		●		●			●	●	●	●	●	●	●	II	●	●	●	●	○	●	●									●	●	●	●	●				●	●	●	●	○	○	○	
Benefits/Costs of Waterway Const.		●			●		●					●						●	●	●	●	●	●	●	II				○	●		●				○					●	●	●	●	●							●	●	●		
Maintain/Improve Waterway Depth		●			●	●	●	●	●			●						●	●	○	○	●	●	●	II					●	●	●									●	●	●	●	●				●	●	●	●		○		
Regulating Carriers Liquid/Dry Bulk Com		●		●			●					●						○	○		○		●		III			○	●				●	●	●	●					●		●	●	●											
Indirect Subsidization Waterway Carr.		●			●		●					●						○			○		●		III				○	●		●				●					●	●	●	●	●										●	
Env. Impact of Carr Usage of Waterways						●					●		●						○					●	III							○									●	●	●	●			○		●		●			○		
Socio-Economic Impact Waterway Dev						●					●		●						○					●	III																●		●	●								●	●	○		
Energy Consumption		●				●	●		●				●					○	○	○		○	●		III				○	●		●									●	●	●	●								○			●	

NOTE: ● Indicates a basic and essential activity that should involve states.

○ Indicates an activity that is optional but where some state involvement may be necessary.

TABLE A-11

DATA REQUIRED FOR AIR CARGO PLANNING

Potential Issue or Problem	Type Issue/Prob.						Level or Scale					State DOT Role						Planning Activities							Priority Group	Data Required by States for Freight Systems Planning Purposes: Traffic Flow								Carrier				Attributes				Physical/Oper.						Direct & Indirect Impacts									
	Intermodal	Line Haul	Terminal	Competition	Infrastructure	Impacts	National	Multi-State	State-level	Regional	Localized	Supportive	Technical Study	Promotional	Coordinative	Capital Invest.	Other Financial	Acquire Info/Und	Forecast: Short	Forecast: Long	Mode Split Anal.	Network Anal.	Economic Anal.	Impact Estimation		Com. Production	Com. Consumption	Commodity Flow	Traffic Flow	Vehicle Flow	Import/Export	Routings	Financial	Operating	Physical Char.	Rates/Tariffs	Shipper	Market	Commodity	Level-of-Serv.	Facility Loc.	Plant Condition	Operating Char.	Usage-Capacity	Unit Oper. Costs	Unit Capital Costs	Noise	Air Quality	Water Quality	Soil Erosion	Ecologic	Economic	Socio-Political	Aesthetic-Visual	Energy Consumption	Safety-Related
National/Regional Air Cargo Term Plan			●		●	●	●					●						●	○	●	●	●	●	●	III	○	○	○	●	●	○		●	●	●					●		●	●			●	○			●	●	●	○		○
Air Cargo Terminal Repl, Modernization			●		●	●					●				●			●	●	○	●	●	●	●	II	●	●						○							●		●	●	●		●	●	●	○	○	●	●	●	○	●	●
Regulatory Modernization				●			●					●		●				○	○				●		III				○		○		●	●	●	○					●		●	●	●												
Routes & Services Market Entry	●			●				●	●			●		●				●	●	○	●	●	●		III	○	○	●			○		○	○	○	○	●	●	●	●																				
Cargo Security			●											●									○		III					●		○																								
Env. Impact of Air Cargo Fac.						●					●		●						○			○		●	III					○										●		●	●			●	○	○		●					
Socio-Economic Impact Air Cargo						●					●		●						○			○		●	III															●		●	●							●	●	○			○
Energy Consumption		●				●	●						●					○	○	○		○	●		III				○	●		●								●		●	●						○			●		

NOTE: ● Indicates a basic and essential activity that should involve states.

○ Indicates an activity that is optional but where some state involvement may be necessary.

TABLE A-12

DATA REQUIRED FOR PIPELINE PLANNING

Potential Issue or Problem	Type Issue/Prob.						Level or Scale					State DOT Role						Planning Activities								Data Required by States for Freight Systems Planning Purposes: Traffic Flow							Carrier				Attributes				Physical/Oper.						Direct & Indirect Impacts									
	Intermodal	Line Haul	Terminal	Competition	Infrastructure	Impacts	National	Multi-State	State-level	Regional	Localized	Supportive	Technical Study	Promotional	Coordinative	Capital Invest.	Other Financial	Acquire Info/Und	Forecast: Short	Forecast: Long	Mode Split Anal.	Network Anal.	Economic Anal.	Impact Estimation	Priority Group	Com. Production	Com. Consumption	Commodity Flow	Traffic Flow	Vehicle Flow	Import/Export	Routings	Financial	Operating	Physical Char.	Rates/Tariffs	Shipper	Market	Commodity	Level-of-Serv.	Facility Loc.	Plant Condition	Operating Char.	Usage-Capacity	Unit Oper. Costs	Unit Capital Costs	Noise	Air Quality	Water Quality	Soil Erosion	Ecologic	Economic	Socio Political	Aesthetic-Visual	Energy Consumption	Safety-Related
System Capacity Add'l Pipelines		●		●			●					●			●			●	●	●	●	●	●	●	III	●	●		●			○	●	●	●						●	●	●	●					○	●	●	●		○		●
Pipeline Extensions into Unserved Areas		●	●		●	●			●	●					●			○	●	○		○	●		III		●														●											○				●
Slurry Pipelines	●			●		●		●	●	●			●		●			●	○	●	●	○	●	●	III	●	●																●	●					○	●	●	●		○		○
Safety: Hazardous Mat'l Transport		●	●			●	●		●			●						○				○	●	●	III				●												●	●	●	●												●

NOTE: ● Indicates a basic and essential activity that should involve states.

○ Indicates an activity that is optional but where some state involvement may be necessary.

freight traffic originated and received from connecting carriers, total carloads or truckloads, total tons, vehicle-miles, net ton-miles, vehicle-hours, power-unit-hours, average hours/miles per power unit, etc.

• *Physical characteristics.* Includes items relating to route structure and plant, including route-miles, track-miles (railroads), power units and rolling stock owned or leased, age of equipment, etc.

• *Rates/tariffs.* Includes published, legal rates charged by for-hire carriers.

Shipper/Consignee Attributes

In some cases, the problem or issue may require detailed examination of the factors affecting shipper behavior (*A-1*). The shipper or the consignee (whoever is paying the freight bill) is the basic decision maker as to mode, carrier, and sometimes route choice. Shipper behavior can be described in terms of the following four types of data:

• *Shipper attributes.* Pertains to plant location, supplier, and operating policy strategic decisions that underlie long-term shipper behavior. For example, the choice of plant location and the choice of suppliers and markets predetermines transport requirements except for volume or level of activity. Thus, component variables include (1) annual production volume, (2) number of establishments (or number of plants and potential commodity flows), (3) location of establishments and modal access, (4) ownership of the freight (hence decision-making responsibility), and (5) pricing structure as it affects transportation decisions (whether price is established at the factory or in the marketplace).

• *Market attributes.* Pertains to the demand for the commodities being produced, which reflects both the short-run equilibrium of supply and demand and the long-range choice of markets. Component variables include (1) amount sold to consuming industries; (2) number, size, and location of consuming industries; (3) characteristics of consuming industries; (4) ownership of the freight; and (5) pricing structure as it affects transportation decisions.

• *Commodity attributes.* Refers to the physical characteristics of the commodity being shipped, as well as information on its handling and use. Component variables include (1) the unit value of the commodity; (2) its density (original and packaged for shipment), (3) shelf life (or the number of days to spoilage or obsolesence), (4) product use (whether in manufacturing or final consumption), (5) inventory control system (single or multiple item), and (6) stock out consequence (net cost, contribution loss, probability of increasing loss with each day of outage, etc.)

• *Transport level-of-service attributes.* Pertains to mode, commodity and shipment size. Component variables include (1) waiting time for shipment to begin, (2) travel time or elapsed time between origin and destination, (3) time reliability, (4) the incidence of loss and damage, (5) the transport tariff charged by the carrier, (6) other costs incurred in making the shipment (such as packaging), (7) minimum shipment size requirements, and (8) special services that may be required (e.g., refrigeration).

Physical and Operating Data

Virtually every issue or problem requires the acquisition of data on facility location, characteristics, and costs. This suggests the need for states (1) to maintain information on plant and rolling stock characteristics and capabilities of carriers serving the state, (2) to monitor operating conditions and environment, (3) to review periodically how efficiently the existing plant is being utilized in relation to its "capacity," and (4) to be able to obtain or develop unit cost data as the need arises. The types of physical and operating data that may be needed are as follows:

- *Facility location.* Includes data identifying the location of the line-haul and/or terminal facility (whether government- or carrier-owned and operated) and data identifying the type, size, age, and general characteristics of the facility.
- *Condition of plant.* Includes various types of qualitative and quantitative data describing the present condition of line-haul and terminal facilities and rolling stock in terms of (1) any restrictions on operations for safety reasons stemming from the condition of the plant; (2) the type, kind, and cost of renewal, repair, or replacement work needed; (3) the amount of wear in comparison with the maximum permissible amount of wear; (4) the contemplated service life remaining in comparison with expected total life; and (5) the market or net liquidation value of the existing plant.
- *Operating characteristics.* Includes data describing performance on a modal system or for specific line-haul and terminal facilities, including all operations relating to commodity transit from origin to destination.
- *Use-capacity.* Includes data describing the actual use, both temporally and spatially, on a modal system or for specific line-haul and terminal facilities. An example of this would be a traffic flow or density map. Also includes information on the capacity or maximum throughput, and associated operating conditions, if this can be conclusively established.
- *Unit operating costs.* Includes data describing the cost of operating modal system or specific line-haul or terminal facilities. Components include line-haul, terminal pickup and delivery, and overhead costs that can be further subdivided into labor, fuel, and maintenance elements.
- *Unit capital costs.* Infrastructure costs. Includes data describing the capital costs of constructing or rehabilitating modal systems or specific line-haul or terminal facilities. Also includes vehicle acquisition and rehabilitation.

Direct and Indirect Impact Data

Impacts can be described in terms of their amount, effect, and value (*A-2*). "Amount" is simply the quantity, such as the number of jobs, the decibel level of noise, or the parts per million of different emissions. "Effect" relates to the response felt by people to the "amount," such as the reduction in personal income, loss of sleep, or increase in per capita incidence of lung-related diseases. "Value" is an indicator of the cost of the impact, which can be tangible (e.g., monetary damages awarded, lost regional product) or intangible. Conceptually, the three terms are interrelated and quantifiable, although in practice most impact assessment is concerned with the "amount" rather than "effect" or "value." Data needed for impact identification and measurement for freight transportation are as follows:

- *Noise.* Data of direct concern identify the noise generation characteristics of freight-carrying vehicles, singly and at different volumes, at various distances from the line-haul facility and under different operating conditions. Data linking freight issues or problems to existing or projected ambient noise levels adjacent to a line-haul or terminal transportation facility and the relation of ambient levels to federal and/or state noise standards (public health) represent site-specific data that would have to be obtained through field investigation and measurements or from local governmental agencies.
- *Air quality.* Data of direct concern identify the unit emissions of different sizes and types of freight power units (e.g., locomotives, tractors, tugboats) operating under different load and terrain conditions. Data linking freight issues or problems to existing or projected ambient air quality levels adjacent to or downwind from a line-haul or terminal transportation facility and the relation of ambient levels to federal and/or state air quality standards (public health) represent site-specific data that would have to be obtained through field investigation and measurements or from local governmental agencies.
- *Water quality.* Data linking freight issues or problems to changes in (1) ground water (e.g., flow and water-table alteration, interaction with surface drainage), (2) surface water (e.g., shoreline and bottom alteration, effects of filling and dredging, and drainage and flood characteristics), and (3) quality aspects (effect of effluent loadings, disturbance of benthic layers, alteration of currents, changes in flow regime, and saline intrusion in ground water) again represent site-specific information of concern primarily in project design and construction and obtainable through field investigation and measurements.
- *Soil erosion.* Data linking freight issues or problems to pollution and siltation potentially stemming from soil erosion from new construction again represent site-specific information of concern primarily in project design and construction and obtainable through field investigation and measurements.
- *Ecologic.* Data linking freight issues or problems to impacts on vegetation and wildlife potentially stemming from new construction again represent site-specific data that would have to be obtained through field investigation and measurements, from public interest groups specializing in ecologic matters, or from state and local environmental protection or conservation agencies.
- *Economic.* Data linking freight issues or problems to changes in the general economic health of the affected surrounding area, including (1) land use (includes both adjacent and "area" land use), (2) tax base (includes both loss through displacement from property taking and gain from increased property values), (3) employment (includes both direct transportation industry and commerce), (4) housing and public services, (5) income (e.g., gains and losses in area per capita income), and (6) damage to economically valued natural resources, again represent site-specific data that would have to be obtained through inter-

views with affected industries/businesses, carriers, local planning boards, chambers of commerce, local officials, and the like.

- *Socio-political.* Includes any data linking freight issues or problems to (1) damage to or use of cultural, scientific, historic, or recreational resources; (2) changes in life style or activities; and (3) perception of project or service costs and benefits by different racial, ethnic, and income level groups. Again, these data are site-specific.
- *Aesthetic and visual.* Includes any data linking freight issues or problems to scenic resources, urban design, blight and decay from transportation line-haul and terminal facilities, etc. Again, these data are site-specific.
- *Energy consumption.* Data of direct concern identify the general energy consumption characteristics of different sizes and types of freight power units operating under different load and terrain conditions. Scale and desired precision of energy consumption-related problems determines the amount of additional site-specific physical data that would be required to compute energy consumption, either in absolute or relative terms.
- *Safety-related.* Data of direct concern identify (1) potential threat to personal safety, (2) cargo loss and damage history and prospects for the future, and (3) the associated costs.

DATA NEEDS IDENTIFIED THROUGH THE ISSUES/PROBLEMS APPROACH

The preceding section dealt with planning processes and data needs responding to 74 individual issues facing state departments of transportation. In order to get an overview of what this means—as a means for establishing priorities in data collection—three frequency analyses were prepared.

In reviewing these three analyses, reported in the following, it should be remembered that of the 74 issues recorded, only 6 (one for each mode) had to do with an over-all plan for a mode or for adding to system capacity for a mode. Thus, 68 out of 74 had to do with very particular kinds of problems; this has an obvious influence on the types of planning activities required to address these problems, and on their data needs.

Frequency of Types of Freight Planning Activities

It is instructive to summarize the planning activities as a check on the reasonableness of the identified data needs. This can be done by tabulating the frequency of the different planning activities by mode, as given in Table A-13.

The results indicate that the preponderance of state DOT planning activity centers on economic evaluation and impact estimation. Lesser involvement is anticipated in short-range forecasting and in network analyses, especially for motor carriers. Virtually all planning activities require acquisition of background information and development of an understanding of the particular issue or problem. The infrequent occurrence of long-range forecasting and mode split analyses stems in part from (1) an inability to prepare satisfactory long-range forecasts for use in freight planning, and (2) the modal orientation of most freight issues.

Frequency of Data Requirements: All Modes, and by Mode and Major Group

To rank data requirements, the following procedure was used. First, the number of times each type of data was used in addressing listed issues or problems was totaled, with a weight of 2 assigned to "dots" and a weight of 1 to "circles." This was done separately by mode and for each priority group within mode. Second, the totals were then divided by 2 and the number of issues/problems in that mode/priority sub-group. This obtained "percentage use" answers ranging from 0 to 1.0. Priority II totals represented the sum of groups I and II, and Priority III totals the sum of all three priority groups.

The results obtained are shown in Figures A-1 and A-2, which show, respectively, the frequency of each type of data by priority category and the frequency of data groups

TABLE A-13

FREQUENCY OF FREIGHT PLANNING ACTIVITIES, BY MODE

MODE	BACKGROUND INFORMATION	SHORT-RANGE FORECASTING	LONG-RANGE FORECASTING	MODE SPLIT	NETWORK ANALYSIS	ECONOMIC EVALUATION	IMPACT ESTIMATION
Rail	M	M	L	L	M	H	H
Motor carrier	M	M	L	M	M	H	M
Ports	M	M	L	L	M	H	H
Inland waterways	M	H	M	M	M	H	H
Air cargo	M	H	L	L	H	H	M
Pipelines	M	M	L	L	M	H	H
All	M	M	L	M	M	H	H

H = high frequency (> 14 weighted activities); M = medium frequency (8.0-13.9 weighted activities); L = low frequency (< 8.0 weighted activities).

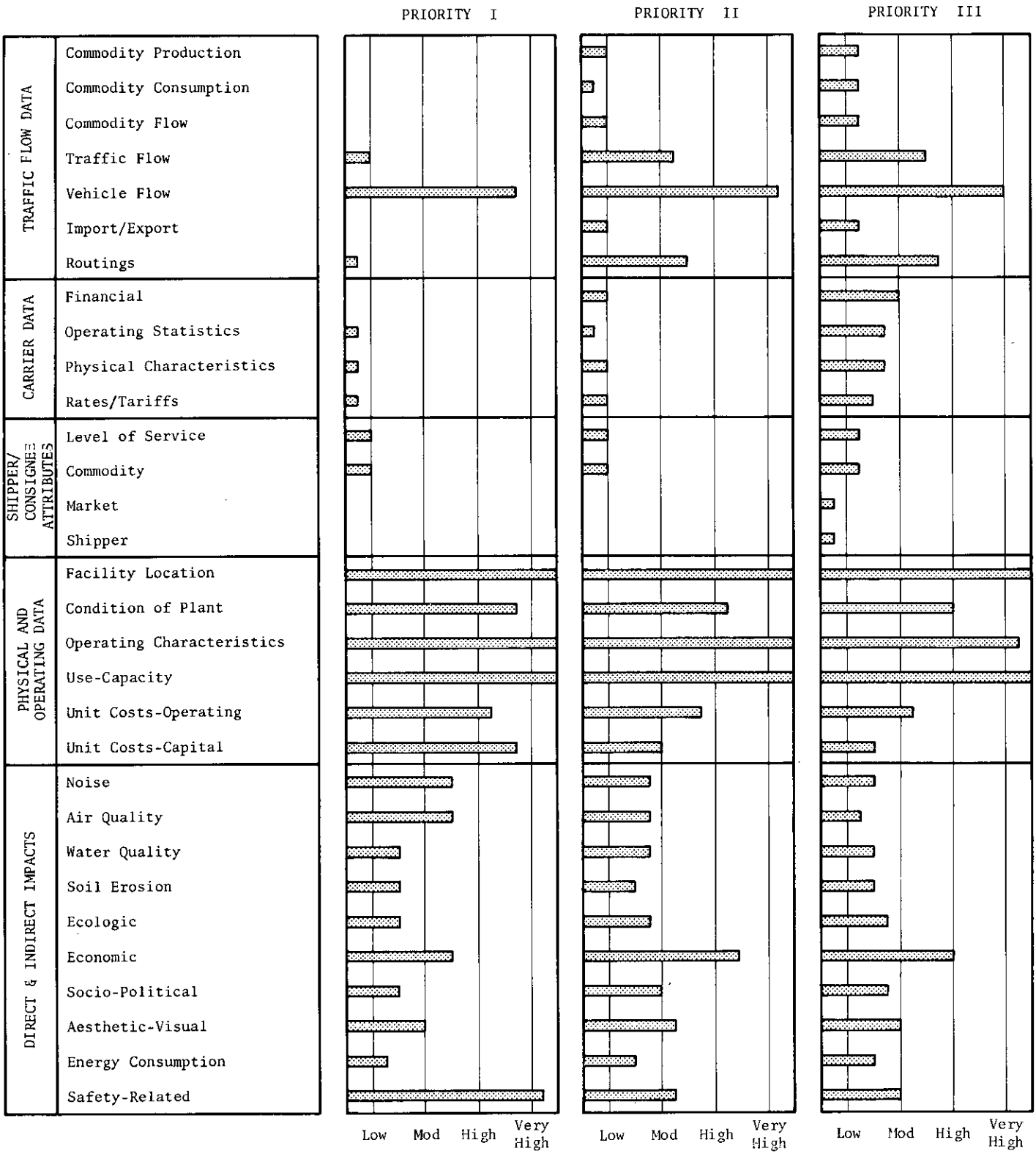

Figure A-1. Data requirements for freight transportation planning, all modes.

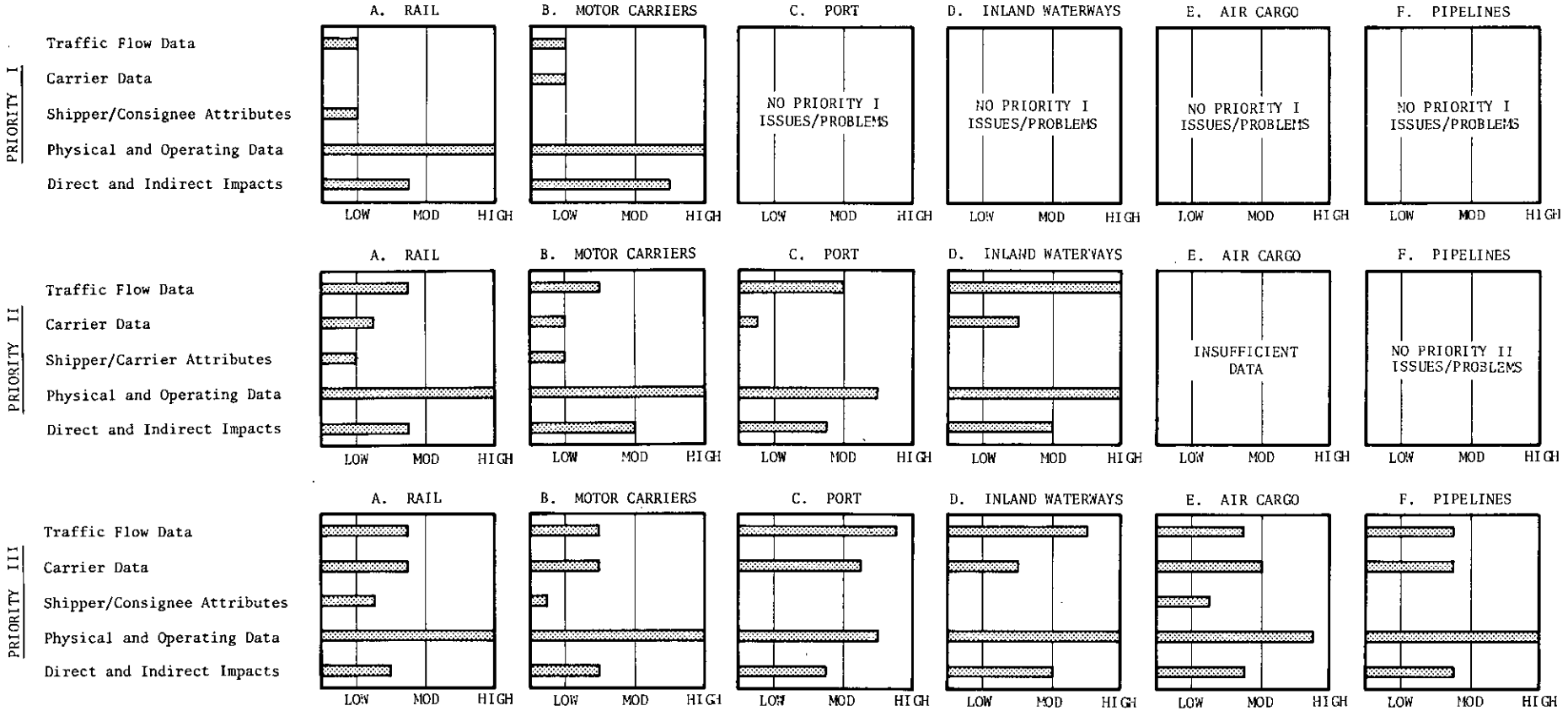

Figure A-2. Data requirements for freight transportation, by mode and major group.

by mode and priority group. From these figures, the following general conclusions can be drawn:

1. The greatest data need apparently is for physical and operating data, especially information on facility location, operation characteristics, use, and capacity. This occurs regardless of mode and priority group. This data need is especially important during the beginning phases of freight planning (Priority Group I).

2. Similarly, there is a strong need for information on vehicle flow and on plant condition and unit costs, both capital and operating.

3. Data supporting impact estimation are of moderate importance, especially data relating transportation system change to public health and safety. Of lesser importance is detailed information on the carriers themselves and the attributes of shippers and receivers.

4. As freight planning becomes more sophisticated (i.e., states become involved with Priority II and III issues), data needs change from a heavy concentration on physically based data to a broader, more comprehensive range of data. The needs for traffic flow, carrier, and shipper/consignee attribtue data increase, whereas the requirements for physical, operating, and impact data decrease. This same pattern is generally true across the modes as well.

5. Priority I data needs center on the rail and motor carrier modes, Priority II on these modes plus ports and inland waterways, and Priority III on all six identified modes.

6. A number of changes were observed as freight planning becomes more sophisticated, as follows:

   (a) Traffic flow data. Initial data requirements largely center around vehicle flow data. Priority II issues indicate a strong need for traffic flow and routing data in addition to vehicle flow data. Priority III requirements show a moderate need for commodity production and consumption, and commodity flow data, as well as specialized information on imports and exports. Over-all, there is a trend toward increasing amounts and diversification in traffic flow data.

   (b) Carrier data. Priority III requirements indicate some need for carrier data, including information on rates and tariffs. Otherwise, requirements for data on carriers appear to be fairly modest.

   (c) Shipper/consignee attributes. Data requirements under all priority groups are modest, reflecting the rather narrow, pragmatic, problem-solving orientation of the issue/problem approach. Data requirements increase as the planning processes become more sophisticated.

   (d) Physical and operating data. Some lessening of data needs can be detected, particularly for unit cost data, as freight planning becomes more sophisticated. This reflects the fact that Priority II and III issues are less physically oriented, more economic or policy oriented in character and thus require a different set of data.

   (e) Direct and indirect impacts. With one exception, a general lessening of data needs can be detected as freight planning progresses in sophistication. The exception is an increasing need for data reporting economic impacts. The relatively low requirement for energy consumption data can be attributed to the fact that most issues or problems are not directly concerned with energy consumption *per se*. This, of course, could change should fuel again become scarce.

In the main, the results obtained appear reasonable. Because some judgment was involved in identifying data needs, the results should be viewed as a general conclusion rather than as precisely determined requirements of data needed for freight planning purposes.

The value of the process described lies not so much in the results obtained for a "typical" state, but that it can be applied by individual states to assess their own unique data needs. States need only follow the same step-by-step process, using staff judgment as to what issues are important. Because of the practical implications of this approach when applied to specific states, a full description of the process employed is included.

ASSESSMENT OF THE ISSUES/PROBLEMS APPROACH

The conclusions reached on data needs are logical and internally consistent. They indicate a strong need for physical and operating data, a somewhat lesser need for traffic flow and impact data, and a relatively low need for shipper/consignee attribute and carrier data.

The issues/problems approach identifies where state efforts are likely; once the efforts are identified, the data that would be needed are then deduced. It has a pragmatic orientation especially useful where planning resources are limited and must be focused on the major issues or problems confronting the state.

On the other hand, the issues/problems approach does have some shortcomings, as follows:

1. The approach reflects today's problems. Although a conscious attempt was made to look ahead, and visualize what issues will be important in the future, such issues are much harder to identify and define. Thus, the data needs do not necessarily represent long-term requirements.

2. The approach used is piecemeal—it divides planning into a large number of smaller problems. It does not directly lead to comprehensive, multi-modal systems planning, which is the ultimate goal in developing a freight planning process.

3. The approach cannot fully identify the data that would be needed for freight "systems" planning on a long-term basis. A good example of this is the down-playing of needs for extensive commodity or traffic flow data containing supporting data on shipper-consignee attributes—data that are at the heart of mode choice analyses and ultimately required were a systems planning approach to be adopted.

4. Data needed for planning process research and development purposes simply do not show up, because the approach is problem oriented.

5. The level of specificity is too low; the results do not

indicate the level or levels of detail required, the degree of aggregation or disaggregation, completeness, etc.

In short, the issues/problems approach represents a pragmatic approach of determining data needs, albeit with some reservations and the necessity of qualifying the results. It is useful for determining priorities for staff work and data collection. Coupled with a close examination of freight planning methods, it provides reasonable answers to freight data needs and priorities.

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A-2. Arthur D. Little, Inc., *Transportation and Environment, Synthesis for Action,* Vol. I: "Summary." Prepared for U.S. Dept. of Transportation, pp. 23-35 (1971), Washington, D.C.

APPENDIX B

DEMAND ESTIMATION

This appendix, the first in a series of four devoted to identifying data requirements through examining systems planning methods and procedures, presents (1) analytical procedures that have been or could be used to estimate freight demand, (2) the major freight demand forecasts that have been made at national and regional levels, and (3) the data needed for demand estimation purposes under different levels of systems planning.

FREIGHT DEMAND OR GENERATION

To the transportation planner the term "demand or generation" means the aggregate amount and composition of the freight generated by the economy or some part of the economy. It is comprised of raw materials, agricultural goods, and manufactured products moving via the nation's transport facilities. The driving force is industrial production and personal consumption. Demand is never static, but ever changing in volume and character. One of the essential prerequisites for statewide transportation systems planning is keeping attuned to on-going change in freight demand.

State freight demand estimation is closely linked to forecasting future state and regional economic activity. Hence, it is essential to have a general understanding and awareness of the relationship between transport demand and a state's (a) industrial production and consumption by major commodity groupings and geographic location, (b) trade relationships with industries in other states, and (c) long-term changes in industrial location, technology, and economics.

Economists work with dollar representations of interindustry transfers, primarily in the manufacturing sectors of the economy; transportation planners, however, are concerned with the physical transfer of goods, measured in tons. It is important to understand both sets of data and the methods for establishing linkages between the two data sets.

How comprehensive must a trade flow or traffic flow data base be for statewide transportation planning? It must be a comprehensive representation of significant traffic movements taking place within a defined area at one or more points in time. It must cover all modes and both for-hire and private operators. However, it need not include local movements; most of the major statistical sources already distinguish between intercity movements and local movements, excluding the latter. The Interstate Commerce Commission defines local service as "transportation performed within a city or town, including the suburban area contiguous thereto." The Census of Transportation similarly defines intracity service as traffic moving to a consignee with an address in the same town or city as the shipper or in a town less than 25 straight-line miles distant; the remaining traffic being considered intercity service. Thus, urban goods movements having both an origin and a destination within the same urban area need not be included in a traffic flow data base for statewide freight planning purposes.

The traditional method for measuring freight demand is through collecting and projecting traffic flow data. Traffic flow is measured in ton-miles, tonnage, and revenue terms (*B-1*). The weight dimension, which represents the quantity involved in production and consumption, enters into all three terms, whereas the spatial dimension, which represents the geographic location of production and consumption, enters into ton-miles and revenue. Traffic flow data

include only the weight of goods actually moving or in transit, as compared to the total amount of goods produced or consumed. The location of various economic activities directly determines the spatial dimension. Five groups of factors are involved in the spatial dimension: (1) quantity and type of commodities, (2) industry structure and technology, (3) the distribution of natural resources, (4) population, and (5) the characteristics of the transportation system—especially unit transport costs. These factors interact as industry seeks to reduce its costs (including transportation) in the long term through plant relocation and market and raw material substitution. The third measure, revenue, includes qualitative as well as quantitative dimensions. For example, higher-quality service commands higher rates. Thus, it has unique attributes.

Freight demand estimation can either be for short-term periods (up to 10 years) or for longer periods—up to 25 years. Most freight forecasts done to date are for less than 10 years; very few are long-term forecasts because technology and the state of the economy are so difficult to predict.

Demand projections typically are more stable the higher the level of aggregation in terms of geography and commodity detail. National projections tend to be more reliable than state projections, which in turn are better than substate (regions or counties). Also, the nation is considered to be a closed economic system, whereas states are not. Furthermore, data availability is far better at the national level than at the state level. For these reasons, state forecasts often begin with, or are checked against, reputable national forecasts of economic growth and change.

PROJECTING FREIGHT DEMAND

Demand projections generally begin with or are based on national or at least multi-state level forecasts. There are several reasons for this: (1) the economic interdependence of states, (2) the large amount of freight transport crossing state boundaries, and (3) the need to maintain consistency and balance among the different modes and across the different geographic areas of the country. This differs considerably from person transport, where it is possible to consider a state or an urban area as being largely separate from the surrounding states or rural hinterland for trip generation purposes. In fact, it usually is not possible to make realistic freight projections on an isolated state basis.

Demand forecasting is far from being a sophisticated, highly developed science. With the exception of recent USDOT work (*B-2*), comprehensive freight projections have not been attempted. Even the USDOT work represents relatively short-range forecasts. Few, if any projections have been attempted at the state level. Although private enterprise has through the years made many projections for marketing and corporate planning purposes, most of these are trend extensions modified sometimes to reflect observed technological or economic changes taking place in different industries. Techniques employed most often are crude and imprecise. More often than not, they do not explicitly recognize the fundamental, long-term technological, economic, and locational forces at work changing the amount and character of freight demand. Because they are not based on the fundamental changes taking place in different industries, freight projections can only be considered as rough estimations or approximations. Techniques for more sophisticated forecasting are available, but data constraints limit their use.

Most freight forecasting is done on a modal basis. Usually, assumptions are made regarding one mode's share of a particular market, if significant intermodal competition does exist. Because demand forecasting cannot be entirely divorced from supply side considerations—as cost and service characteristics do affect demand, especially over the long term—a better approach would focus on aggregate demand and leave the division of freight among competing modes until later.

Forecasting Methods

In their work for SCAG and CALTRANS, Bruck et al. (*B-3*) identified a total of 19 different methods having potential use in freight planning. They classified methods as (1) quantitative, (2) time-series analysis and projections, and (3) qualitative. These methods are briefly reviewed in the following paragraphs. In addition, the two most important quantitative methods are described in greater detail later in this section.

Quantitative Methods

If time-series data are available and sufficient prior analysis has been conducted to indicate explicit and valid relationships between the factor to be forecast and other economic variables, quantitative methods can be used. Table B-1 summarizes the four types of quantitative methods deemed most useful in projecting freight demand for statewide transportation systems planning purposes.

The most commonly used quantitative method is regression analysis. For example, freight volumes are related over time to a single macroeconomic variable, such as gross national product (GNP). Obviously, the macroeconomic variables must be reasonable, reliable, and predictable. Different regression analysis techniques can be used, ranging in complexity from ordinary least squares regression analysis to multiple regression analysis (*B-4*).

Time Series

Time-series analysis and projection, or trend extension or extrapolation, is the oldest and still the most widely used forecasting method. It differs from quantitative methods in that no attempt is made at explaining or relating demand to other stable, predictable "causal" variables. Time-series projections are useful so long as there is stability in the phenomena being forecast. Consequently, such projections require the existence of high-quality, stable, temporally based data covering a long time span. In addition to basic trend extension, other methods include moving averages, the Box-Jenkins method, exponential smoothing, the X-11 method, and motionary triangles (*B-3*).

The process provides a rapid assessment of freight traffic trends. It can be readily computerized. On the other hand, confidence in the results is more limited than with quantitative methods. It is good only for short-range forecasts.

Qualitative Methods

The third group of forecasting methods is strictly qualitative. They may be used when no information or very little time-series data exist. Their main use, then, is in situations where some type of forecast (especially long-range) is required and only preference information exists. Often these methods are coupled with discussions of alternative future scenarios that a capable analyst can present for a particular project. These methods are far more effective if they can be combined with one of the quantitative methods discussed earlier. Qualitative methods include the Delphi method, market research, panel consensus, factor analysis, historical analogy, and anticipation surveys (*B-3*).

TABLE B-1

SUMMARIES OF QUANTITATIVE METHODS FOR PROJECTING FREIGHT DEMAND

1. *Regression Analysis:* The ordinary least squares method can be applied to any single-equation model that is purported to capture a one-way flow of causality from a set of independent variables to a dependent one. The dependent variable is the one to be forecast, using the specified historical relationship as the foundation. Accuracy is usually quite good, statistically. Requires ten or more observations of time series, cross-sectional, or pooled data. Typical examples of independent macroeconomic variables include gross national product, different production indices, and population. Generally the number of explanatory variables is limited. Stepwise regression analysis provides a systematic way of selecting the best explanatory variables from among a number of independent macroeconomic variables. The technique is particularly useful when the choice among explanatory variables is not clear cut. There is often, however, a high degree of multicolinearity among the determinants in the regression, which makes the predictive value of such models questionable.
2. *Econometric Models* (Simultaneous equation systems): These are systems of independent regression equations that describe some sector or region of economic or transportation activity. As a rule, these models are relatively expensive to develop and operate, but they tend to be more effective than ordinary regression models in expressing the causalities and interactions involved and consequently will forecast turning points more accurately. In general, they represent the most accurate method and attractive framework to handle regional and statewide commodity flows. Same data requirements as before.
3. *Input-Output Models:* These reflect the interindustry or interregional flows of goods and services in the regional (or national) economy and its markets. Considerable effort must be expended to use these models properly and additional detail, not normally available, must be obtained if they are to be applied to specific regions. Accuracy is fairly good. Extremely detailed data are required, including base-year outputs, employment, and payrolls; interindustry transactions; base-year final demands; base-year trade flows; and projected final demands.
4. *Economic Base Studies:* To some extent, economic base studies are the heart of classical regional location theory. These studies reflect the changing economic and industrial base in local areas and regions. They are extremely useful in identifying the industrial mix of a local community, capturing short-term changes in industrial composition, and generating employment and freight flow information on its industries.

Source: Bruck et al. (*B-3*).

Economic Base Studies

In this family of techniques, industries are divided into two categories—basic activities, which bring money into a region from the "outside world," normally by exporting goods and services outside the region, and nonbasic activities, which include all other industries.

The conduct of an economic base study is generally described by three major steps: (1) identify those activities within the region which export or are in some way basic, (2) predict growth in those basic activities, and (3) from these growth measurements, identify growth in nonbasic activities. The precision with which this analysis is done is the major determinant of the data requirements.

The simplest approach is to categorize entire industries or classifications of industries as basic or nonbasic. Retail trade might thus be classified as nonbasic, whereas manufacturing would be basic. This method requires only very generalized data on industry location, employment, sales, etc., but the results obtained in such a generalized study may not be very accurate.

An initial refinement of the industry categorization results from the realization that each industry produces goods both for import and for export, and as such, is neither wholly basic or nonbasic. The "location quotient" is useful for making such an estimate:

$$\text{Location quotient} = \frac{\text{Percent of national production provided by state (or region)}}{\text{Percent of national personal income, population, value added, etc., produced by state (or region)}}$$

The criticism of the location quotient is that it normally leads to an underestimate of exports because of the likelihood of cross-hauls when dealing with whole industries or industry groups.

The most exacting and most data-demanding approach is to survey shippers to determine exactly the quantities that are imported or exported from a region. This has been done for large regions, as is documented in "Commodity Transportation Survey" of the Census of Transportation; data on smaller regions, however, can be difficult to obtain. Data requirements are given in Table B-2.

Given a change in the transport network, the next task is the projection of future activity in basic industries. This is best done through a survey of affected industires (*B-5, B-6, B-7*), or a market analysis of critical industries (*B-8*). Many of the techniques available, however, are not well suited to predicting industry or area localized demand changes, and the analyst should assess carefully the scope of the problem before forecasts are made.

Once growth in basic industries is specified, it becomes possible to determine the impacts on income, employment, and other indicators through linkage effects. This is normally done through calculation of "multipliers" that indicate for each dollar of sales, or each employee added to a basic activity, the probable growth in the identical measure for a nonbasic activity. Once again there are varying degrees of precision in methodology. One method is simply the calculation of basic ratios; i.e., the ratio of a given

measure (say gross product) produced by basic industries to that produced by nonbasic industries. This calculation may be for a single year or changes between years, with the latter method yielding perhaps the most accurate results (*B-9*).

One example of an economic base analysis of employment is shown in Figure B-1.

As the previous description implies, economic base analyses are quite simple both in concept and in practice. They have been used extensively for forecasting purposes (mostly of employment) simply because by projecting future prospects for expansion in certain basic activities one can easily derive forecasts of total activity. These economic forecasts can then, by indirect methods, be used to yield population forecasts.

Economic base studies have not always yielded convincing results. Isard (*B-9*) has compiled a detailed discussion of the method's conceptual and technical shortcomings, of which there are many. Probably the most serious drawback of the economic base concept is the demonstrated lack of time stability of multipliers. Multipliers have a tendency to change with time and with regional size and structure. This has serious implications for use of a multiplier as an aid in forecasting.

Input-Output Models

Input-output analysis is a method for quantifying the relationships that exist in a region between producing sectors and the consuming sectors. It is a systematic method of accounting which, among other functions, can be used to trace the effects of any action through each part of a regional economy (*B-10*).

The basis of the analysis is the input-output table. This table displays the manner in which the production of each industry is distributed among other industries and the consuming sectors of the economy. An example of the table format is shown in Figure B-2. Data to produce this table can be obtained by a census of sales of each industry or by a census of purchases (ideally both should be done).

From the basic input-output table, a table of "technical coefficients" is derived. The entries in this table (example shown in Fig. B-3) are defined as the amount of input required from each industry to produce one dollar's worth of the output of a given industry.

These coefficients are calculated for consuming sectors only and can be expressed either as monetary values or in physical terms such as tons. This table is then read as follows: "An increase of $1.00 in output of industry A will necessitate purchases of $0.17 from industry D." This table is indicative of the initial or "first-round" effects of increasing production in given industries. These are known as direct effects.

To determine indirect or total increases in output that occur as the result of increased production, a table of direct and indirect requirements (as shown in Fig. B-4) is produced. The direct and indirect results of changes in final demand are important because they comprise the final expansion in output of the entire economy. In essence, this table represents multiple iterations of the calculations performed to produce the direct requirements tables. The iterations are normally done by computer using matrix algebra. The entries in Figure B-4 are read as follows: "For an increase in production of $1.00 in industry A, $0.25 of output will be required from industry B, $0.28 from industry C, $0.41 from industry D, etc."

TABLE B-2

DATA NEEDED FOR ECONOMIC BASE ANALYSIS

STEP	METHOD	DATA REQUIRED
Determination of industry type	Industry categorization	Industry characteristics.
	Location quotient	Industry production statistics. Regional population, value added, income, sales, employment, etc.
	Survey	Quantity imported and exported by industry or by firm.
Projection of future "basic" production	Market analysis	Present and future transport cost. Present and future commodity prices. Knowledge of trading patterns.
	Survey	Quantity of future production by firm or industry.
	Interregional input-output analysis	Purchases, sales, and employment by industry; inventory changes; future final demand.
Projection of economic indicators	Multiplier analysis	Employment data for base year by industry. Income data for base year by industry. Sales data for base year by industry. Tons shipped for base year by industry.

WICHITA EMPLOYMENT, 1940 AND 1950, CLASSIFIED BY THE TYPE OF MARKET SERVED

	Employment		Market Served: Local (Service)		Market Served: Regional, National, and World (Basic)	
	1940	1950	1940	1950	1940	1950
Total	52,091	88,575	37,148	59,325	14,943	29,250
Agriculture	4,074	3,276	1,109	1,442	2,965	1,834
Total non-agricultural	48,017	85,299	36,039	57,883	11,978	27,416
Mining	925	971	50	71	875	900
Construction	2,837	7,297	2,837	7,297	–	–
Manufacturing	8,692	23,931	2,705	4,605	5,987	19,326
Food and kindred products	2,624	3.243	1,232	1,193	1,392	2,050
Textile mill products	16	53	16	53	–	–
Apparel	146	205	–	–	146	205
Furniture	135	459	135	459	–	–
Printing	1,208	1,714	686	1,200	522	514
Chemicals	172	242	–	–	172	242
Petroleum	572	548	–	–	572	548
Metals	985	1,973	–	–	985	1,973
Machinery	637	1,857	–	–	637	1,857
Transportation equipment	1,561	11,937	–	–	1,561	11,937
Other manufacturing	636	1,700	636	1,700	–	–
Transportation, communications, public utilities	4,473	6,833	3,752	5,576	721	1,257
Wholesale trade	3,003	4,616	1,498	2,774	1,505	1,842
Retail trade	10,216	16,542	8,617	14,509	1,599	2,033
Finance, insurance, and real estate	3,115	4,118	2,729	3,447	386	671
Service	12,105	16,711	11,200	15,324	905	1,387
Public administration	1,765	3,437	1,765	3,437	–	–
Industry not reported	886	843	886	843	–	–

Source: Federal Reserve Bank of Kansas City, Data based on Census of Population, 1940 and 1950.

BASIC-SERVICE RATIOS AND MULTIPLIERS, WICHITA

	Basic-Service Ratio	Regional Employment Multiplier
1. Based on total employment: 1940	$\frac{14,943}{37,148} = 1:2.5$	3.5
2. Based on total employment: 1950	$\frac{29,250}{59,325} = 1:2.0$	3.0
3. Based on change in employment: 1940–1950	$\frac{14,307}{22,177} = 1:1.6$	2.6

Figure B-1. Economic base analysis as applied to employment. Source: Ref. B-9.

The foregoing discussion describes what is known as regional input-output analysis. There has been growing interest in interregional input-output analysis as a means to predict economic effects of changed trading patterns. Interregional input-output analysis required construction of yet another table, as shown in Figure B-5. This table shows flows not only between industries but also between regions, and it can be used to estimate changing requirements that will be placed on the transportation network.

The chief advantages of input-output tables are best expressed by Isard (*B-9*): "(1) they record concisely, in an internally consistent manner, a large amount of information about a regional economy and interrelations of its sectors; (2) they impose a desirable statistical discipline on data collection agencies and empirical investigations; (3) they reveal gaps in data and may help in filling them; and (4) they present an economy in perspective and facilitate comparison of the magnitudes of its major sectors and bonds with other economies."

Against these advantages are arrayed some formidable drawbacks, both conceptually and practically. One of the primary problems with implementing an input-output analysis is the huge data set required, particularly for interregional analysis. For the analysis to be useful in planning for transportation, commodity detail must be good. Probably 100 commodities must be included, although to streamline the analysis for a single region, only critical commodities need to be detailed, with the remainder lumped into general classifications. Transaction table data exist now at a national (*B-11*) and state scale (*B-12*). Some data have also been collected at a regional level. Because of the expense of these surveys (individual firms must be sampled), small samples are employed with a consequent sacrifice in reliability. Interregional transactions data (*B-12*), which have been synthesized from a large variety of existing data sources, are more generalized and unreliable.

A conceptual problem with input-output models is that when they are used for forecasting, the technical coefficients (i.e., the components of output as shown in Figs. B-3 and B-4) are generally assumed to remain constant. In long-range forecasting this critical assumption may not be valid because of changes in technology.

For the input-output analysis to be used in transportation planning the dollar values of transactions must be converted to tonnage of commodities. This necessitates difficult conversions; two examples of processes using such conversions are given later.

Summary

Several conclusions can be drawn: First is the dependency of most methods on historical and/or present-day commodity or traffic flow data. Second is the need for macroeconomic data and indices of anticipated future economic performance to use as the "independent" variable. Third is the interdependency of freight or commodity flow and macroeconomic data in forecasting. Freight demand forecasts can be no better than estimates of economic growth and change. Finally, there is a need to include in the forecasting process information on long-term locational, technological, and transport cost and service.

RECENT FORECASTS OF FREIGHT DEMAND

This section presents recent applications of some of the foregoing methods to freight demand estimation at the national, state, and substate levels. This is being done partly to identify data needs and sources more explicitly, and

		Processing Sector						*Final Demand*					
	Outputs[1] → / Inputs[2] ↓	(1) A	(2) B	(3) C	(4) D	(5) E	(6) F	(7) Gross inventory accumulation (+)	(8) Exports to foreign countries	(9) Government purchases	(10) Gross private capital formation	(11) Households	(12) Total Gross Output
Industry Producing	(1) Industry A	10	15	1	2	5	6	2	5	1	3	14	64
	(2) Industry B	5	4	7	1	3	8	1	6	3	4	17	59
	(3) Industry C	7	2	8	1	5	3	2	3	1	3	5	40
	(4) Industry D	11	1	2	8	6	4	0	0	1	2	4	39
	(5) Industry E	4	0	1	14	3	2	1	2	1	3	9	40
	(6) Industry F	2	6	7	6	2	6	2	4	2	1	8	46
Payments Sector	(7) Gross inventory depletion (−)	1	2	1	0	2	1	0	1	0	0	0	8
	(8) Imports	2	1	3	0	3	2	0	0	0	0	2	13
	(9) Payments to government	2	3	2	2	1	2	3	2	1	2	12	32
	(10) Depreciation allowances	1	2	1	0	1	0	0	0	0	0	0	5
	(11) Households	19	23	7	5	9	12	1	0	8	0	1	85
	(12) Total Gross Outlays	64	59	40	39	40	46	12	23	18	18	72	431

[1]Sales to industries and sectors along the top of the table from the industry listed in each row at the left of the table.
[2]Purchases from industries and sectors at the left of the table by the industry listed at the top of each column.

Figure B-2. Example of input-output (hypothetical transactions) table for industry purchasing. (Source: Ref. B-10. *From* The Elements of Input-Output Analysis, *by William H. Miernyk. Copyright © 1957 by Northeastern University, renewed 1965 by Random House, Inc. Reprinted by permission of Random House, Inc.)*

Input Coefficient Table
Direct Purchases per Dollar of Output

Industries Purchasing

Industries Producing	A	B	C	D	E	F
A	16c	26c	3c	5c	13c	13c
B	8c	7c	18c	3c	8c	18c
C	11c	4c	21c	3c	13c	7c
D	17c	2c	5c	21c	16c	9c
E	6c	0	3c	36c	8c	4c
F	3c	11c	18c	15c	5c	13c

Figure B-3. Example of direct purchases table. (Source: Ref. B-10. *From* The Elements of Input-Output Analysis, *by William H. Miernyk. Copyright © 1957 by Northeastern University, renewed 1965 by Random House, Inc. Reprinted by permission of Random House, Inc.)*

Direct and Indirect Requirements per Dollar of Final Demand

	A	B	C	D	E	F
A	$1.38	.25	.28	.41	.27	.23
B	.45	1.21	.16	.19	.12	.24
C	.27	.38	1.38	.23	.17	.39
D	.35	.25	.25	1.53	.65	.41
E	.35	.26	.31	.39	1.28	.25
F	.38	.35	.22	.30	.21	1.32

Figure B-4. Example of direct and indirect requirements table. (Source: Ref. B-10. *From* The Elements of Input-Output Analysis, *by William H. Miernyk. Copyright © 1957 by Northeastern University, renewed 1965 by Random House, Inc. Reprinted by permission of Random House, Inc.)*

partly to record national forecasts that can be used as a resource in statewide freight planning and a control within which state and substate forecasts can be developed. Because present forecasting methodology inadequately accounts for locational, technological, and transport cost and service changes, a further section discusses the limiting assumptions of present methods and the need for supplemental data to be worked into the demand estimating process.

National Projections

National-level projections of freight demand represent the most successful application of statistical forecasting techniques to estimate freight demand. Most national forecasting work done by regulatory agencies at the federal level is for very short time periods (six to eight quarters). These forecasts are of limited value for freight system planning and have not been included in Table B-3. Longer-term, single-mode forecasts have been made for special rail studies and for air cargo movements. Results from these studies should be used with caution because a number of explicit assumptions must be made to determine modal share of the market. For example, the study done by Temple, Barker, and Sloan for USRA (*B-28*) produced two sets of forecasts using different assumptions on the quality of rail service. The major drawback of single-mode studies is that they do not consider the total amount of freight transport needed for a given level of projected economic activity. This problem is avoided in several of the forecasts that utilize fairly comprehensive methods tied to the total performance of the economy.

Perhaps the most significant work done to date in preparing national projections for use in transportation planning is that by Jack Faucett Associates for the USDOT (*B-2*). Using a specially developed input-output model, Faucett has developed a series of historical and projected ton, ton-mile, and revenue estimates for the different transport modes, based on forecasted growth of the national economy. The freight modes separately identified include rail, domestic water, local and intercity for-hire and private trucking, domestic air carriers, and pipelines. An input-output model translates aggregate final demand (GNP) into detailed interindustry trade estimates and associated requirements for commodity transport. The method ensures that the requirements of individual components of the economy are consistent, not only with future estimates of GNP, but also with personal consumption and business and government expenditures. Input-output methodology permits direct estimation of nearly all freight transportation, as the interindustry transactions are especially appropriate for translating GNP into detailed industry estimates and their associated requirements for transport of commodity freight.

The Faucett study relied heavily on Bureau of Labor Statistics (BLS) projections of trends to 1980. Historical and projected nontransportation demands were based on an adaptation of the 1958 national input-output table developed by the Office of Business Economics (OBE) as projected to 1965, 1970, and 1980 by BLS, and included the sectoral breakdown and interindustry coefficients of the interagency growth project (*B-13*). The individual transportation demands were developed through disaggregation within the over-all BLS final demand. Major modifications of interest to freight projections included (1) the collapsing of 82 OBE industry (nontransportation) sectors into 37; (2) disaggregation of the OBE transportation sector into 24 commercial transportation sectors; (3) delineation of 16 private transportation modes previously contained within the industry sectors and final demand; (4) preparation of ton, ton-mile, and revenue estimates by sector; and (5) further delineation of sector estimates by mode. The historical 1965 and the three 1980 demand projections are based on those in "Patterns of U.S. Economic Growth" (*B-14*). In addition to the 1980 central tendency BLS GNP projection, which assumes a 4.3 percent growth rate, 4 percent unemployment, and a historical rate for the purchase of durable goods, alternate projections assuming a 3.5 and a 5.0 percent growth rate were also made to represent upper- and lower-limit GNP estimates.

TABLE B-3

MAJOR NATIONAL FREIGHT DEMAND PROJECTIONS

MODE	SPONSORING AGENCY	PERFORMING AGENCY	TITLE OF FREIGHT DEMAND PROJECTION AND DATE	MEASURES FORECAST	FORECAST YEARS	METHODOLOGY EMPLOYED	LEVEL OF DISAGGREGATION	MACROECONOMIC VARIABLES EMPL.	TRAFFIC FLOW DATA USED
Rail, domestic water, for-hire trucking, private trucking, domestic air, pipelines	USDOT	Jack Faucett Assoc.	Transportation Projections: 1970-1980 (Mar. 1973)	Tons, ton-miles, revenues (1971 $)	1980	Input-output model	37 industry sectors 40 trans. sectors	GNP	ICC 1% waybill, Census of Trans., COE waterborne, etc.
International air, water	USDOT	Planning Research Corp.	Trans-oceanic Cargo Study (Mar. 1971)	Tons	1970 1975 1980	Trend extension with exponential smoothing	Imports/exports to 54 countries; 200 detailed commodity groups, 21 broad groups	None	U.S. Customs Bureau data
Rail, truck, domestic water	MARAD	Kearney Management Consultants	Domestic Waterborne Shipping Market Analysis (Feb. 1974)	Tons	5-yr. Incre. thru 2000		BEAR regions; 19 commodity groups	Pop., comp., income, earnings by BEAR	ICC 1% waybill, Census of Trans., COE waterborne, etc.
Rail (Con-Rail + 6 eastern RR)	USRA	Temple, Barker & Sloane	Forecast of Traffic and Revenues 1974-1980 (Oct. 1974)	Tons and revenues (1973 $)	Yearly 1974-1980	Trend extension with market res.	11 individual RRs; 14 commodity groups	GNP	RR annual reports to ICC
Domestic air cargo	U.S. Aviation Advisory Comm.		The Long-Range Needs of Aviation (Jan. 1973)	Ton-miles	5-yr. Incre. thru 2000	Forecasting equation	Domestic, international, airmail, air freight, express	GNP	Historical (1946-1964) ton-mile data
	Air Trans. Assn. of America		Industry Report: ATA Airline Demand Forecasts (July 1969)	Ton-miles	1975 1980 1985	Regression equation based on econometric analysis	Domestic, international, airmail, air freight, express	GNP	
	Civil Aeronautics Board		Forecast of Scheduled Domestic Air Cargo for the 50 States, 1971-1975 (Feb. 1971)	Ton-miles	1970-1975	Regression equation based on econometric analysis	Domestic, airmail, air freight, express	GNP	

Normal input-output practice is to attach freight costs to consuming industries requiring that input. However, the Faucett study found that the producing sector can give better projections of freight service requirements and of modal shares, because tons of shipable outputs can be provided in association with total output and the outputs of a particular industry are far more homogeneous in terms of value and weight than its inputs. Thus projections are based on producing industry output.

In 1965 and 1970 estimates of freight revenues were largely based on data from published sources, including:

MODE	PUBLISHED SOURCE
Rail	ICC statistics for Class I and II railroads.
Domestic water	CE statistics on tons and ton-miles and ICC statistics on average revenue per ton carried.
For-hire trucking	ICC statistics for Class I, II, and III regulated carriers, supplemented by estimates of the revenues of nonregulated carriers and trucking by warehousing (based on 1963 Census of Transportation data) and small carriers without employees (based on Census of Population, Business, and Transportation data).
Private trucking	Cost structures and mileage distributions developed by Faucett.
Domestic air	CAB statistics.
Pipeline	ICC statistics for interstate pipelines and OBE estimates of total revenue and its ratio with interstate traffic.

The modal shares projected for 1980 are based on assuming (1) the tonnage shipped by each industry increased proportionately with its output; (2) the proportion of tonnage shipped by private trucking remained constant; and (3) the tonnage shipped by railroads, for-hire trucking, domestic water, and pipelines would conform to trends observed on the bases of time-series data. Thus the modal breakdown is essentially one of trend extrapolation.

The main value of the Faucett study lies in the tables produced showing domestic freight revenues (in 1958 and 1971 dollars), tons, and ton-miles by mode and sector generated from the 1965 and 1970 historical and 1980 3.5 percent, 4.3 percent, and 5.0 percent growth rate final demands. The work has been done in a form that will permit future updating. The various components that affect the 1980 projections are largely trend-based and do not anticipate major shifts in government transport policy, programs, or technological development.

Although the Faucett study is perhaps the most successful application of input-output technology to national transportation projections, its output is too aggregated to be of direct use at the state level. Its principal value lies in the development of a method that ties together transportation and economic data.

State Projections

Whereas an appreciable amount of freight demand forecasting has been done at the national level, little has been done at the state level. Perhaps the principal cause of this is the almost total lack at the state level of both freight transport statistics (except rail) and suitable macroeconomic data around which to develop causal relationships. Lack of the former inhibits even such simple techniques as trend extension, whereas the latter has constrained the development of econometric models to predict future economic conditions. Virtually every freight forecast made at the national level utilizes GNP in some fashion or another.

With the rise of interest in regional economics, attention has been directed toward econometric tools for predicting the performance of a state's economy. A number of states have commissioned or directly developed input-output models. Unfortunately, these models have rarely found much use in transportation planning, because the outputs have not been converted to tons, ton-miles, and revenues among the different modes of freight transport. Even when done, developing the detailed statistical data necessary to develop the model has proved to be a major and difficult undertaking.

During the past several years, however, a new tool—a multiregional input-output model—has been developed in work done by Polenske (*B-20*) and others to investigate the transportation requirements in different regions (states) of the United States.

As previously discussed, a national input-output model provides a consistent framework within which the interdependence of the transport sector with the rest of the economy can be described and analyzed. However, the results from that type of model are of limited use in statewide freight planning. A multiregional input-output model provides a basis for consistent estimates of transportation requirements by industry and region, or state, and the many interactions between changes in the rest of the economy and transportation can be studied in considerable industrial and regional detail. This model appears to have appreciable promise for study of policy-oriented issues involved in statewide freight planning and thus should be of great interest to state DOTs.

To implement the model, a comprehensive set of regional data using the 87-industry OBS classification system covering all industries and states was assembled for the United States. Five major sets of multiregional input-output data were compiled for each state: (1) base-year outputs, employment, and payrolls; (2) 1963 interindustry flows; (3) 1963 interregional trade flows; (4) base-year final demands; and (5) 1970 and 1980 projected final demands. A set of input-output tables was then prepared for each state for 1963 consistent with national 1970 and 1980 BLS projections. The six components of final demand were then projected to 1970 and 1980 to produce estimates of regional outputs and commodity flows among regions.

In determining interregional shipments among the states,

three fixed trade coefficient models have been tested within the multiregional input-output concept: point estimate gravity, column coefficient, and row coefficient. The column coefficient was ultimately chosen for use in preparing the final computations. An obvious alternative would be a linear programming model, which has not been tested with this multiregional input-output concept. Linear programming models require rather detailed and extensive sets of transportation cost data and treat commodity flows between states as net flows (i.e., cross-hauling of commodities cannot occur). The aggregate nature of the interregional shipments data used does indicate cross-hauling on a state-to-state basis.

Extensive written information has been prepared on the multiregional input-output model (*B-15, B-16, B-17, B-18, B-19, B-20*). In addition to books, reports, and articles, the data are available on computer tapes through USDOT. This includes data for 79 industries in the 50 states and the District of Columbia; the state-to-state tonnage trade data for 1963, 1970, and 1980 in 1963 dollars (DOT tapes R5 and R6); and the 1963 state-to-state trade flows for 41 states in values and tons; for both the six modes of transportation and the total flows (*B-1*). Table B-4 gives further details on the multiregional input-output tapes that are available. A user's guide containing (1) a general description of the multiregional accounting system, (2) a description of the basic data used to set up the multiregional model for the base year 1963 and providing some detail and rationale on the methods used to ensure consistency both internally and with national input-output figures, and (3) information needed for implementation of the model has also been prepared (*B-22*). State-to-state flows were estimated from origin-destination data on commodity movements, values of area output, imports by port of entry, and

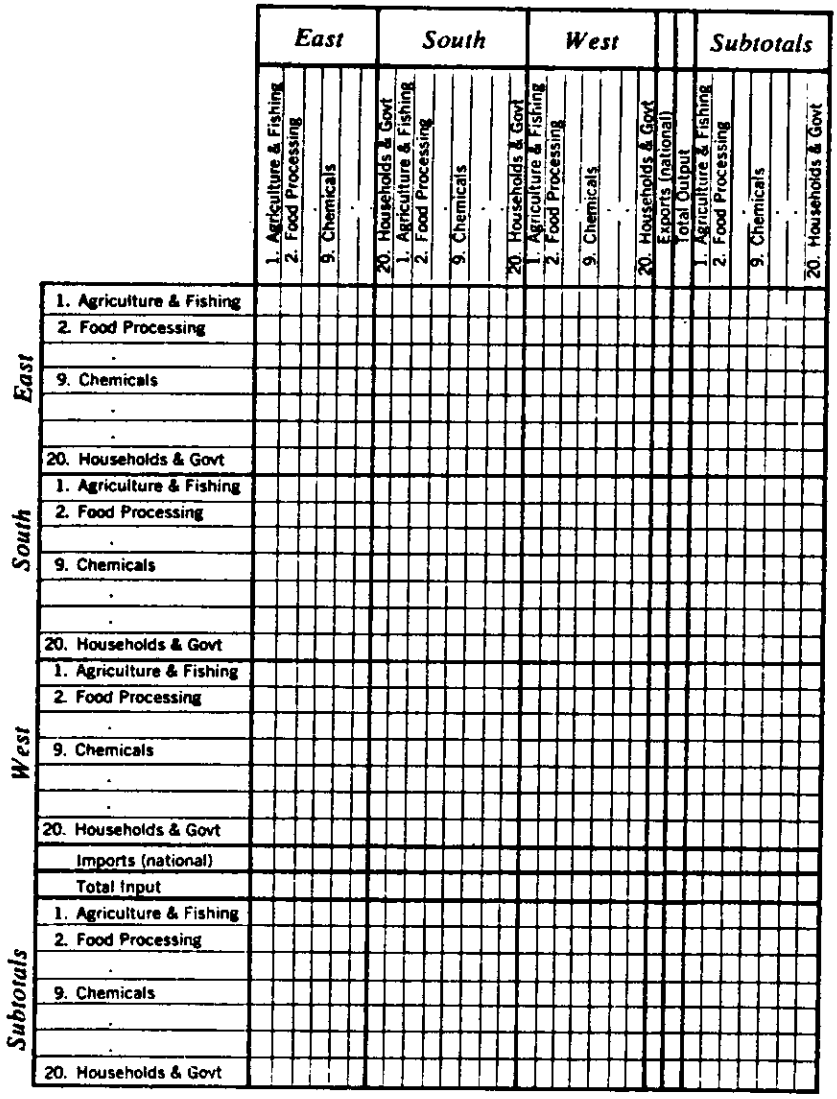

Figure B-5. Example of interregional and regional input-output table. (*Source: Ref.* B-10. *From "Interregional and Regional Input-Output Analysis: A Model of a Space Economy," by Walter Isard,* The Review of Economics and Statistics, *XXXIII (Nov. 1951), 321, Harvard Univ. Press. Copyright 1951 by the President and Fellows of Harvard College. Reprinted by permission.*)

demand for goods at various locations. For each industry, ton measures of state-to-state trade were tabulated or calculated from various data sources. These initial estimates were balanced by proration to total shipments of the commodity, measured in tons, for each state of origin. State ton flows were next converted to value terms. The estimates of intrastate trade included elements of industry output not contained in the value of shipments. Finally, the matrices

TABLE B-4

MULTIREGIONAL INPUT-OUTPUT (MRIO) DATA TAPES SUBMITTED TO THE DEPARTMENT OF TRANSPORTATION SEPTEMBER 1973

DOT TAPE NO.	MRIO DATA SET NO.	TAPE FILE NO.	DATA SET POSITION(S)	MATRIX DIMENSIONS	TITLE
R1	1	1	1-19	88 × 53	1947, 1958, and 1963 Final Demands.
		2	1	88 × 53	1963 Commodity Credit Corporation Adjustment to Federal Government Final Demand.
		3	1	88 × 7	1947 (58$) and 1958 (63$) Final Demand Deflators.
	2	4	1-9	88 × 53	1947, 1958, and 1963 Outputs, Employment and Payrolls.
		5	1	88 × 4	1947/58 Output Deflators.
	3	6	1-12	88 × 53	1970 and 1980 Final Demand Projections.
	4	7	1-51	87 × 87	State Secondary Matrices, 1963.
		8	1	87 × 87	Sum of State Secondary Matrices, 1963.
R2	4	1	1-51	87 × 87	State Input-Output Tables, 1963.
		2	1	87 × 87	Sum of State Input-Output Tables, 1963.
R3	5	1	1-61	52 × 52	Trade Flows from JFA (PREDUD), 1963.
		2	1	52 × 52	Sum of Trade Flows from JFA (PREDUD), 1963.
		3	1-61	53 × 53	Adjusted Trade Flows (POSTDUD), 1963.
		4	1	53 × 53	Sum of Adjusted Trade Flows (POSTDUD), 1963.
R4	6	1	1-2	80 × 52	1970 and 1980 Total Final Demands Without Residual and Secondary.
	4	1	3	80 × 52	1963 Regional Transfers, Out.
	4	1	4	80 × 52	1963 Service Industry Residual.
	6	2	1-2	80 × 52	1970 and 1980 Projected Outputs.
	6	3	1-61	53 × 53	1970 Projected Trade Flows
	6	4	1	53 × 53	Sum of 1970 Projected Trade Flows.
	6	5	1-61	53 × 53	1980 Projected Trade Flows.
	6	6	1	53 × 53	Sum of 1980 Projected Trade Flows.
R5	7	1	1-61	52 × 52	1963 Tonnage Trade Flows.
	7	2	1	52 × 52	Sum of 1963 Tonnage Trade Flows.
	7	3	1-61	52 × 52	1963 Commodity Trade Prices.
R6	7	1	1-61	52 × 52	1970 Projected Tonnage Trade Flows.
	7	2	1	52 × 52	Sum of 1970 Projected Tonnage Trade Flows.
	7	3	1-61	52 × 52	1980 Projected Tonnage Trade Flows.
	7	4	1	52 × 52	Sum of 1980 Projected Tonnage Trade Flows.

Source: Memorandum dated July 1, 1975, from Karen K. Polenske to potential users listing the multiregional input-output publications and computer tapes available.

of trade flows were balanced to output and consumption controls of the multiregion input-output model by proration of differences using an iterative technique.

The value of the multiregional input-output model is that it provides virtually the only complete source of information on state-to-state commodity flows, both existing and projected. By covering all 50 states and the District of Columbia, this information not only contains commodity flows originating and/or terminating in a particular state, but it also permits identification of external movements having some likelihood of passing through the state. Other state-level input-output models accompilsh the former; none known to the researchers can accomplish the latter. Although some freight traffic flow data can be disaggregated to the state level (e.g., the ICC/FRA Railroad Waybill Sample), such data are not uniformly available across the modes or, even if available nationally, cannot or have not been disaggregated to the state level for technical or disclosure reasons.

The data sets and projections forming the outputs of the multiregional input-output model do have shortcomings. First, they are too old and do not reflect economic changes occurring in the 1970s. As a forecasting tool, the use of input-output methodology depends on the quality of the projected final demands. Whether population projections or other external increases in demands are used to determine final demands, the predicted changes in outputs will only be as realistic as the assumptions. Another difficulty stems from the conversion of interindustry flows measured in dollars into freight flows measured in tons. There is no easy way of doing this that will ensure precise results, especially when many of the commodity groupings are quite heterogeneous. Such a conversion process requires economic rationality of freight movement, which does not exist. There is no known way of analytically replicating cross flows of commodities, choice of mode, circuity of routing, etc., that arise from corporate structures and institutional practices. Also, there is no way of validating the estimates using actual data—this will be the case until a comprehensive data set at state-to-state level is assembled.

Economic Area Projections

Industrial activity in the producing and consuming sectors is the primary determinant of commodity flows. Thus the organization of data on economic activity has a strong bearing on the resulting organization and availability of data on commodity flows. Use of states as economic analysis regions has one serious drawback—in many instances they do not represent particularly rational economic divisions within the United States. For example, the New York metropolitan area functions as an single unit, yet it covers major portions of three states.

As a part of the National Water Assessment program carried out by the National Water Resources Council, a series of regional economic projections have been prepared that can also be used for forecasting interregional commodity flows. These projections are based on centers of economic activity defined by the Bureau of Economic Analysis (BEA) in the U.S. Department of Commerce. Each area includes not only the major production or service center, but also the surrounding area depending on that generator. The resulting areas, which are basically separate though not independent economic units, are called BEA economic regions (BEARs). A total of 173 BEARs cover the United States. They are larger than SMSA's and smaller than Census-defined production areas, neither of which cover the entire country. In only five cases can BEARs be aggregated to form states: Hawaii, Alaska, California, Nevada and Arizona (the first two are single BEARs). Figure B-6 shows the location of different BEA economic regions (*23*).

A series of "accounts" has been developed for each BEAR for the years 1950, 1959, 1962, 1968, and 1969. These regional accounts include total population and employment, total personal income, and total earnings (dollars) by economic sector. In all, 49 different economic sectors have been identified. In addition to these historically oriented accounts, regional earnings by industry projections have also been made to 1980, 1990, and 2000 (*B-24*).

To be useful for freight planning purposes, the foregoing production and consumption data must be married with traffic flow data between the 173 BEARs to be of use in statewide freight planning. This has been done in the MARAD Domestic Waterborne Shipping Market Analysis Study. Its purpose was "to develop marketing aids and strategies to assist domestic marine carriers to achieve full realization of their inherent role to serve the nation's transportation needs" (*B-25*). One of the major study tasks was to assemble present freight flows and forecast future growth. Included in this task was assembling a computerized data base containing the region-to-region transportation flows of all commodities by surface transportation modes. Also included in this task was forecasting the future level of flow in five-year increments through the year 2000, using BEA employment and income data as the forecast basis.

Regional (Substate)

Obviously, state-to-state or BEA region-to-region freight projections would be of great value in estimating interstate traffic and of some value in estimating the growth in through traffic. But what about freight that originates and terminates within the state?

Unfortunately, relatively few attempts have been made to develop freight projections on a substate basis. Although rough projections can readily be made, the problem lies in finding a methodology and supporting data that are solidly based enough to instill confidence in the final results. As part of its transportation development program, Ohio experimented with extending Battelle's DEMOS population and economic forecasting model to the year 2000. Freight projections were made by mode (rail, motor carrier, water, and other) of tons received by county for 11 economic groups (*B-26*). Results could never be validated because of the lack of county-level freight production and consumption data. Other states have used (Kentucky), or are planning to use, DEMOS.

A number of states have commissioned the preparation of forecasts on a modal basis. For example, Pennsylvania had R. L. Banks & Associates project the demands for rail

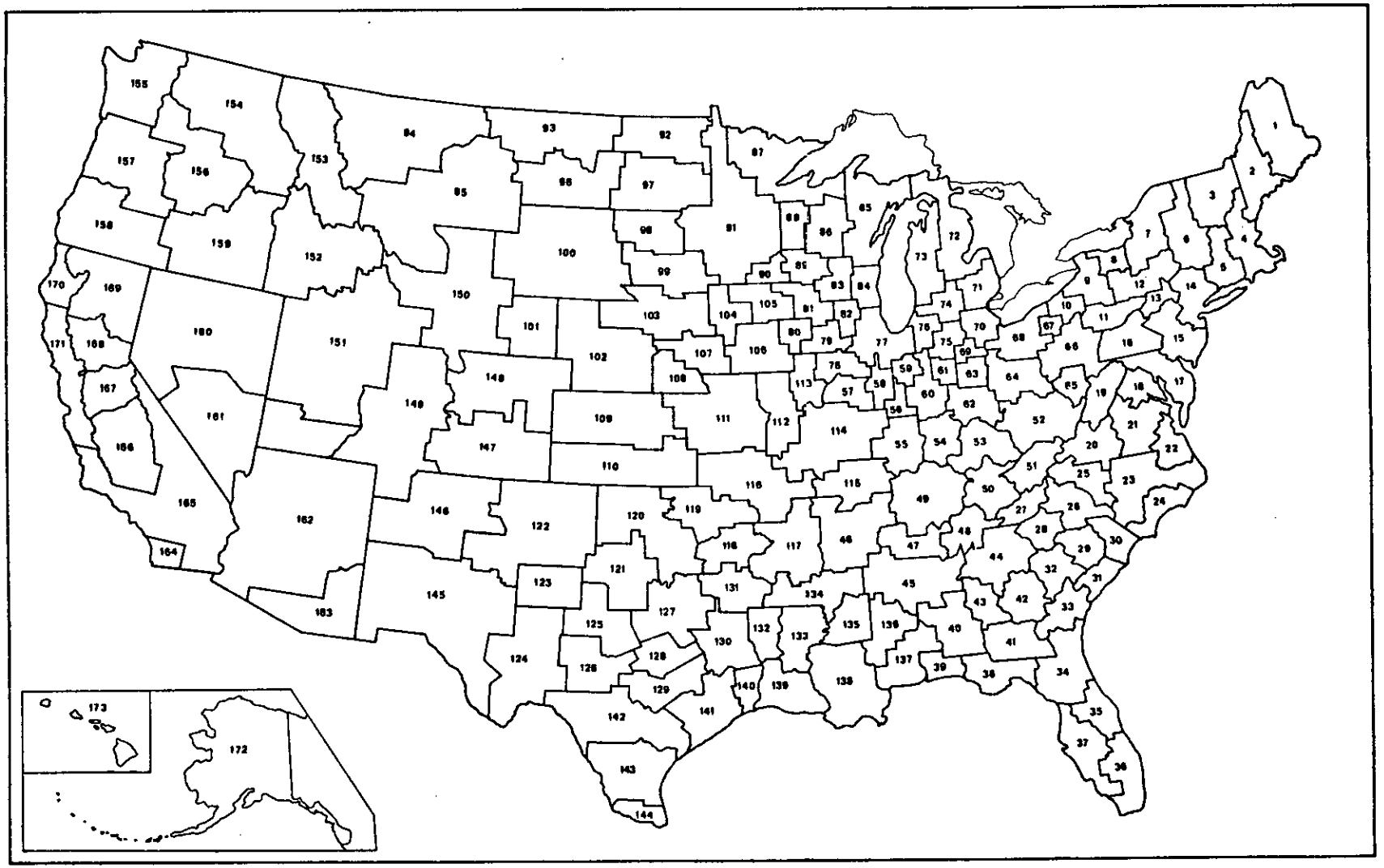

Figure B-6. BEA economic areas delineated by the Regional Economics Division, Bureau of Economic Analyses, U.S. Department of Commerce.

service through examining historical relationships between levels of industrial and general economic activity on the one hand and railroad freight tonnage on the other. State population and economic forecasts were used with the ICC/FRA 1 percent waybill sample summarized to county groups. Texas Transportation Institute, in preparing air cargo forecasts for the Texas Airport System Plan, used trend extensions coupled with "share-of-the-market" techniques to project 1970, 1975, and 1980 demand for different sized hubs (*B-27*). Base data consisted of Civil Aeronautics Board and Air Transport Association of America forecasts and historical data on the cargo handled at Texas airports *vis-a-vis* national totals. Many other examples could probably have been cited as examples of state efforts to prepare modally oriented freight forecasts on a substate basis, had the documentation been published and disseminated.

Several observed characteristics of substate projections are worth noting. First is the heavy dependency on historic traffic generation or flow data. Second is reliance on simple methods, such as trend extension and share proration, tied into more major economic or transport forecasts. Finally, with the exception of air cargo and rail freight, the lack of forecasts is due in large part to lack of a suitable data base.

DATA REQUIREMENTS, SUMMARY AND CONCLUSIONS

Summary

The state of the art for forecasting freight demand at the state level is primitive. Forecasting typically has been (1) short-range, (2) national in scope, and (3) trend oriented. Little work has been done to develop techniques suitable for application at the state level. Thus, states find themselves starting essentially from "ground zero."

Two key points need to be emphasized. First, the ability to prepare reliable demand estimates can never be better than forecasts of economic growth and change. Improvement in the latter must come first; yet little work is being done in this area. Second, trend extensions and simple correlations of traffic flow data with macroeconomic variables must be replaced by more advanced techniques that take into account economic interdependencies, differential regional growth and specialization, and technological change. Only in this way will there be significant improvements in tactical (short-range) and strategic (long-range) demand estimates.

Desired Capabilities

In summary, the demand estimating capabilities being sought by states are the ability to:

- Prepare reliable tactical estimates of anticipated freight demand changes for the state as a whole and for specific corridors on a modal basis using conventional estimating procedures.
- Prepare strategic estimates suitable for statewide policy or systems-level planning (e.g., forecasts for a statewide master plan, by mode).
- Develop commodity production/consumption and flow estimates as an output of statewide or regional economic forecasting based on advanced econometric models.
- Quantitatively relate freight flows to commodity production and consumption, thus tying together trade and traffic flow data.

Obviously, some capabilities are more difficult to achieve than others. Thus, the foregoing must be structured into several alternative program levels reflecting different program investment and staff expertise.

Program Levels

Freight demand estimates may be categorized into three different program levels. These categories and their data needs are as follows:

Stage I. Under this program level the main emphasis is on preparing short-range freight demand estimates for individual modes using trend extension techniques. This stage combines demand forecasting and modal split via modal traffic flow data extrapolation. The product would be approximate estimates of changes in tonnages and ton-miles. Data needs center on assembling available published traffic flow data, national-level modal forecasts, and short-range projections of the national and state economies.

Stage II. Under this program level the capabilities achieved in Stage I would be extended to prepare more refined short-range aggregate forecasts using structurally based forecasting techniques (e.g., regression analysis) based on projected changes in the national and state economies. Data needs center around extending traffic flow data and particularly on assembling detailed information on the state's economy and where it is headed. State DOTs would be dependent on other agencies for economic projections.

Stage III. Under this program level the capabilities achieved in Stages I and II would be further extended to prepare aggregate traffic flow forecasts from separate commodity production and consumption estimates. Under Stage III, projections would (1) be mode independent; (2) be tied into econometric models projecting state-level or regional economic activity; and (3) account for locational, technological, and transport cost-of-service considerations not possible with time series projection methods. Data needs center around those required to apply advanced econometric techniques to estimate both short- and long-range freight demand.

Data Required for Demand Estimation

Data required for demand estimation are indicated in Table B-5. Data requirements shown are additive; that is, Stage II would include those given for Stage I, and Stage III would include those given for Stages I and II.

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TABLE B-5

INFORMATION OR DATA REQUIRED FOR DEMAND ESTIMATION

CATEGORY	INFORMATION OR DATA NEEDED
	(a) Stage I
Traffic flow data	1. Carload Waybill Statistics for 1966, 1969, 1972 and more recent versions, preferably on an annual or biennial basis. 2. Census of Transportation 1963, 1967, 1972. 3. Waterborne Commerce of the United States on an annual or every-other-year basis. 4. FHWA Nationwide Truck Survey data.
Modal forecasts	1. Modal forecasts made at the national level by governmental agencies, trade associations, etc. (see Table B-1).
National and state economy	1. For a list of national projections, see Table B-3.
	(b) Stage II
Traffic flow data	1. Tabulations of traffic flow data by mode on a regional basis for intra-state freight and on a region to state and multi-state areas (and vice versa) for originating and terminating interstate freight. Possible for rail, water, air modes upon special request to governmental agencies. 2. Approximations of the above for motor carrier and pipeline traffic flow data.
Modal forecasts	1. Projections made by major carriers serving the state.
State economy	1. Detailed forecasts of state economic growth by county or sub-state region. 2. Detailed information on commodity production and consumption by region assembled from data available to federal and state governmental agencies. Information should be assembled for several points in time.
	(c) Stage III
State-level economic methodology, information	1. Inputs and outputs from any specially developed model of the state's economy. See Table B-3. 2. Detailed output information from similar econometric models applied at the national level by governmental agencies and private financial institutions. See Table B-3.

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APPENDIX C

MODAL CHOICE MODELING

The purpose of this appendix is to (1) describe freight mode choice models having potential application in statewide transportation systems planning and (2) identify the specific data requirements. This appendix is the second one devoted to identifying data requirements.

In statewide freight planning the question frequently arises as to the number of tons of freight, by type, that will use a particular mode if existing conditions are altered due to changes in the transport system or as a result of transportation policy decisions. Investments and regulatory decisions depend on these estimates. Therefore, mode choice is an important step in the freight planning process.

In the past, freight transportation has been viewed as a key element in the marketing and distribution process of free enterprise. The states have relied on competitive market forces and private enterprise to define the shape of freight transport. The role of the states has been predominantly one of improving the resource allocation of freight transport through regulatory controls. But times change, and so will the role of state involvement, particularly with respect to public investment in (1) freight facilities, (2) various subsidy programs, (3) regulation, and (4) research and development. If current trends continue, as demonstrated by the Northeast railroad crisis, state DOT's may find themselves also thrust directly into participating in the ratification of freight carrier rate proposals, the evaluation of new freight services and route applications, and the appraisal of proposed freight service cutbacks and abandonment-of-service petitions.

To take a more active role in these particular freight planning and evaluation activities, states must develop analytical capabilities and tools necessary to evaluate freight transportation policy, system, and facility options or plans. Freight modal choice analysis procedures are one such tool.

Mode Choice Model Development

An extensive search of pertinent literature on freight modal split uncovered a wealth of information on theoretical frameworks for modeling mode selection, but little on actual application of these models. Most of the work to date has been done (1) within a research rather than planning context and (2) by universities rather than by federal or state governments. The lack of application partly stems from difficulties encountered in assembling required data and from the limited amount of freight systems-level planning done to date.

Meyer et al. (*C-1*) in 1959 were the first to attempt to develop an analytic freight modal choice model. Using the least cost criterion, their model selected the lowest cost mode of transportation by length of haul. Mode choice attributes were limited to just two variables: (1) freight rate charged, and (2) inventory costs based on average commodity value, transit time, and shipment size differences between modes.

United Research, in a study prepared for the Department of Commerce in 1963, also recognized the importance of including total transport costs as an explanatory variable

in the selection of mode of transport. They stated: ". . . the preferred method of shipment and the intensity of this preference will be roughly proportional to the saving in total cost . . . and shipping costs should, therefore, reflect the 'actual' (rather than current tariff costs) inherent in the system" (*C-2*, p. X-4).

This theme that transport users attempt to minimize their total logistic costs was further advocated by Milne (*C-3*). He also advanced the concept that quality-of-service measures play an integral role in the mode selection decision-making process. Milne concluded that service quality could be measured by three general attributes: safety, reliability, and transit time (accessibility, line haul, and frequency of service).

In 1965 Roberts (*C-4*, *C-5*), through an economic evaluation of transport companies, suggested that the expected utilization of a new service could be determined if the market values of the new and present services were established. The independent variables in his model were shipping rate and service quality measures that consisted of such elements as travel time, reliability, and other indirect transport costs not considered in the rate.

Church (*C-6*) in 1967 analyzed the 1963 *Census of Transportation* (*C-7*) to determine the extent to which the distribution of freight traffic among modes can be explained by the elements of commodity, size of shipment, and distance between origin and destination. He concluded (*C-6*, p. 6) that ". . . size and distance factors account for most of the variability in the highway share of freight transportation, with commodity becoming a significant third variable, especially for large shipments." Surti and Ebrahimi (*C-8*) and Buhl expanded on Church's study, and Buhl (*C-9*, p. 13) deduced that "there is a substantial inverse correlation between the highway-carrier share of total tons originated by manufacturing establishments and plant size." Employment was used as the measure of the size of the firm.

Beuthe and Moses (*C-10*) developed a freight modal split model based on the economic criterion of profit maximization. In their model, profit is calculated by

$$\text{Profit} = \text{price at destination} - (\text{cost of production} + \text{shipping rate} + \text{value of time}) \qquad \text{(C-1)}$$

Profit is expressed in dollars, so a monetary value must also be calculated for the value of time. The interest cost of money foregone in transporting a product is defined as the value of time. Therefore, if the dollar value of time can be determined, time costs could be added to production and shipping dollar costs to provide a single monetary variable for mode selection. The transportation alternative that offers the shipper the largest profit margin is chosen. Although the model does not consider the effects of commodity or service quality measures on mode choice, it does underline the importance of including shipper attributes in freight modal split methodology.

A number of other investigations (*C-11*-*C-17*) also attempted to identify the variables that affect the freight transportation modal selection process.

In 1969, Charles River Associates (*C-11*) in a study of rail and truck transportation suggested that trucking offers several superior service advantages to shippers: smaller shipment size, faster deliveries, better service reliability, more frequent service, and a number of other lesser advantages. The authors stated that "practically all of these advantages are consequences of fundamental technological differences between the two modes" (*C-11*, p. 21). Also, that if service differentials (size of shipment, time in transit, and service quality) between modes could be reduced the rail share of traffic would increase.

Dueker (*C-12*) in 1969 described an ideal motor carrier commodity flow data set. His investigation concentrated on motor carrier flows, because this mode was believed to be the most difficult for which to obtain data. The analysis attempted to relate the flow data set to the data requirements for a freight modal split model. The following elements of the ideal data set were identified as essential to the mode selection process.

- Location of shippers and receivers.
- Commodity type.
- Completeness of service.
- Transit time (line haul).
- Weight of shipment.
- Rate.
- Actual routings.

Herendeen in a discussion on the merits of various mode selection variables concluded (*C-13*, p. 31) that ". . . there are eight variables particularly germane to the freight modal split task," as follows:

- Transportation cost.
- Weight of shipment.
- Distance.
- Transit time.
- Reliability of service.
- Frequency of service.
- Commodity type.
- Size of firm.

This list was further reduced to five variables for testing and predicting modal split. Herendeen argued that because transport cost is highly interrelated with weight and distance these two factors could be replaced by the single measure, transport cost. Firm size as a variable was found to be statistically questionable in estimating mode shares; consequently, it was not included in his modeling effort.

Both Allen and Beuthe (*C-14*) held similar views on the selection of variables, including:

- Volume of production/consumption.
- Price at destination.
- Transit time.
- Transport cost.
- Value of time, expressed as an interest rate.
- Measure of safety.

Stucker (*C-14*) suggested that the following characteristics should be incorporated in freight mode-split modeling:

- Transit time.
- Convenient shipping times.
- Reliability.

- Loss and damage measures.
- Other costs (packaging, or special handling costs and terminal charges).

Meyer and Straszheim (*C-15*) recognized the importance of properly identifying the type of commodity being shipped. They noted that freight traffic is particularly sensitive to the shipper's willingness to pay for a specific transportation service and that this service is related to the following commodity attributes:

- Density or weight.
- Volume—demand for transportation services per unit of time.
- Value—expressed as the dollar value of the product per unit measure.
- Perishability.
- Fragility.
- Volatility.
- Seasonality or peaking characteristics.
- Adaptability to liquid transport.

Willingness to pay was described as ". . . a negative function of density, volume of traffic per time period, seasonal steadiness, and schedule flexibility, and a positive function of value per unit of weight, perishability, and most of the other characteristics enumerated" (*C-15*, p. 171).

Wallace (*C-16*) in his 1971 study on air cargo transport suggested that mode selection decisions are determined on a basis of minimizing the total cost of transportation, where transport cost consists of four component parts:

- Handling cost (pickup and delivery costs).
- Terminal cost.
- Line-haul cost.
- Cost of ownership.

Handling costs are described as functions of size of shipment, number of parcels per consignment, and access or egress distance/time. Terminal costs depend on consignment size, number of parcels and type of mode that utilize the facility. Line-haul charges are defined as "that portion of the shipper's costs assignable to the carriage of goods between terminals but excluding the terminal charges" (*C-16*, p. 69). These costs are affected by the characteristics: mode of transport, vehicle limitations (weight and volume capacity), particular shipping and handling requirements, density or weight of a consignment, and vehicle average load factor. The fourth component, cost of ownership, includes such elements as cost of insurance, depreciation, packaging cost, and a value of investment that is a function of transit time.

Hutchinson expanded on Wallace's work and concluded (*C-17*, p. 19) that "modal shipping decisions are influenced by the freight pricing regime as well as the distributional structures of various industrial organizations." He recognized the importance of consignment size, distance of haul, and commodity type as principal factors in mode selection. Hutchinson advocated use of disaggregate data over zonal aggregate characteristics for freight modal split analysis.

These early research efforts focused principally on the identification of the various attributes that affect freight mode choice decisions. These attributes, which fall into four general areas—commodity attributes, transport system attributes, shipper attributes, and market attributes—and are presumed by various researchers to affect the freight shipper's modal selection process are given in Table C-1. This compilation of factors, which extends an earlier list contained in Appendix A, was derived from an extensive search of literature on freight modal selection. These studies usually were not concerned with development of a comprehensive, quantitative-type model. A few suggested very general, theoretical frameworks for a model of mode selection, but none were applied, tested, or calibrated to the level necessary for statewide planning.

PROBLEMS IN FREIGHT MODAL SPLIT ANALYSIS

In considering the specific attributes given in Table C-1, and the developmental work done to date by different researchers, several conclusions can be reached:

- No consensus exists on the relevancy of different attributes as they relate to freight mode choice modeling.
- Rank ordering of attributes will be different, depending on (1) the commodity involved, (2) the characteristics of transport modes available, (3) the geographic location, and (4) the unique needs of individual shippers, among other things.
- The attributes are not independent.
- Data availability regarding the listed attributes varies greatly.
- Several of the attributes do not lend themselves to quantitative measurement.

Although the foregoing has hampered research somewhat, the major problems in freight mode split analysis are (1) the availability of data, (2) the heterogeneity of aggregate commodity groupings, and (3) the difficulty of determining and including all relevant variables in modal analyses. These three problems interact and vary in importance, depending on the level of aggregation incorporated within the analysis.

Data aggregation can either be by commodity type or by geographic area. The smaller the number of commodity types (the higher the commodity aggregation), the more likely it is that there will be a mix of commodities in each grouping that will make estimation of mode split difficult. The larger the geographic aggregation, the more difficult it is to use the resulting data in statewide planning.

Problems occur for both low or high levels of aggregation. At a low (disaggregate) level, the sampling variability is usually high for existing data sets, or the data are simply not available, or the collection and processing of data become unmanageable. At a high (aggregate) level, the sampling variability is usually lower and data coverage is better, but the likelihood of nonhomogeneity of commodity type is heightened.

Presently, traffic flow data, a major data input to modal split analyses, are quite limited. Almost all flow data sources (such as ICC 1 percent waybill and *Census of Transportation* data) cover national freight flows at a high level of geographic aggregation, thus preventing many researchers from applying their models to detailed data.

TABLE C-1

FREIGHT MODAL SELECTION ATTRIBUTES

ATTRIBUTE TYPE	DESCRIPTION
(a)	Shipper Pertains to plant location, supplier, and operating policy strategic decisions that underlie long-term shipper behavior. For example, the choice of plant location and the choice of suppliers and markets predetermines transport requirements except for volume or level of activity. Thus, component variables include (1) annual production volume, (2) number of establishments (or number of plants and potential commodity flows), (3) location of establishments and modal access, (4) ownership of the freight (hence, decision-making responsibility), (5) pricing structure as it affects transportation decisions (whether price is established at the factory or in the marketplace), (6) size of establishment (or number of employees), (7) shipper's awareness and the knowledge of alternative mode transport options, and (8) ownership or loyalties to specific means of transport.
(b)	Market Pertains to the demand for the commodities being produced, which reflects both the short-run equilibrium of supply and demand and the long-range choice of markets. Component variables include (1) amount sold to consuming industries, (2) characteristics of consuming industries, (3) ownership of the freight, and (4) pricing structure as it affects transportation decisions.
(c)	Commodity Refers to the physical characteristics of the commodity being shipped, as well as information on its handling and use. Component variables include (1) type of commodity shipped, (2) the unit value of the commodity, (3) its density (original and packaged for shipment), (4) shelf life or the number of days to spoilage or obsolescence, (5) fragility or susceptibility to damage, (6) its volatility or likelihood to change, (7) seasonality, (8) adaptability to liquid transport, (9) product use (whether in manufacturing or for final consumption), (10) inventory control system (single or multiple item), and (11) stockout consequence (net cost, contribution loss, probability of increasing loss with each day of output, etc.)
(d)	Transport level of service Pertains to mode, commodity, and shipment size. Component variables include (1) waiting time for shipment to begin, (2) travel time or elapsed time between origin and destination, (3) time reliability, (4) the incidence of loss and damage, (5) the transport tariff charged by the carrier, (6) other costs incurred in making the shipment (such as packaging), (7) distance shipped, (8) frequency of service (fixed or flexible service, number of convenient scheduled shipping times), (9) routing availability and restrictions, (10) completeness of service (or number of transfers or interchanges involved), (11) modal operating constraints (such as minimum shipment size requirements, and availability and condition of equipment), and (12) special services that may be required (e.g., refrigeration).

Hartwig and Linton (*C-18*) attempted to gather their own disaggregate-level freight data base for modal split analysis and concluded that either carriers and shippers do not collect the data in any form, or if they do, they are generally very reluctant to provide the information without strict guidelines for its use.

It is still not at all clear that disaggregate data acquisition warrants the associated additional time and cost required. Proponents of the disaggregate approach argue that high levels of aggregation are usually also highly heterogeneous in composition. However, heterogeneity may not be so serious a problem in statewide analysis.

Some advocates of the disaggregate approach argue that certain variables (i.e., inventory-related variables) affecting mode choice are not suitable for use in models based on higher levels of aggregation. Conceivably, these variables could be incorporated into aggregate models if the problem of heterogeneity did not exist.

Clearly the debate over disaggregate versus aggregate analyses will continue for some time; but considerable improvements can still be made in freight modal split analyses within existing data limitations.

- Further experimentation with aggregating commodities and zone structures into homogeneous groupings is possible. Two investigators (Kullman (*C-41*) and Tucker (*C-27*)), in particular, have experimented with the possibility of forming aggregate homogeneous commodity groups that were different from the SIC 2- or 3-digit commodity codes used to compile *Census of Transportation* data.
- Further experimentation with the various types of mathematical formulations for estimating mode split shares is definitely warranted. This is addressed in the next section.
- Models should be developed for a particular type of analysis. Models are not intended to be comprehensive; that is, analyses of mode choice are dependent on the degree of aggregation desired. To illustrate, a macro-level analysis, based on one or two independent variables for predicting aggregate modal share, may be satisfactory for national studies but completely unacceptable at the level of individual origin-destination pairs. Likewise, a model designed to analyze a particular commodity flow may be appropriate for some studies but too detailed for a general national-level study.

FREIGHT MODAL SELECTION MODELS

The purpose of mode selection models is to allocate freight demand among competing modes. Given the amount of freight, X, to be transported from an origin, i, to a destination, j, for a specific time period, the mode share, T_{ijk}, becomes the amount of freight transported from origin i to destination j by mode k. The general form of the freight modal selection model is:

$$T_{ijk} = P_k(X_{ij}) \cdot X_{ij} \qquad \text{(C-2)}$$

and

$$P_k(X_{ij}) = f(C, T, S, M) \qquad \text{(C-3)}$$

in which

T_{ijk} = tonnage of freight shipped by mode k from origin i to destination j;

$P_k(X_{ij})$ = percentage of freight shipped by mode k from origin i to destination j;
X_{ij} = total tonnage of freight shipped from origin i to destination j within a specified time period;
C = commodity related attributes;
T = transport level of service attributes;
S = shipper attributes; and
M = market attributes.

Because the sum of freight flows for each mode must equal the total amount of freight shipped, the constraint of

$$\sum_k T_{ijk} = X_{ij} \qquad \text{(C-4)}$$

must also apply to Eqs. C-2 and C-3.

Freight mode split is a major component of the larger process comprised of demand estimation, distribution, mode split, and network analysis. Most of the models discussed in this section focus on mode split only; a few also incorporate demand estimation and distribution into a single package. Obviously there is a strong need for compatibility between the demand estimation and mode split phases, something which has not been achieved to date.

The general characteristics of the eight types of mode split models discussed in detail are given in Table C-2. Physical distribution system and micro-level logistics models are not included because there is some doubt whether they would be useful in the macro-scale planning characteristic of statewide systems planning (*C-53*). Each model is discussed in terms of its (1) type, (2) general formulation, (3) application, (4) data requirements, and (5) evaluation for use in statewide transportation systems planning applications.

Multistage Procedure (Simultaneous Equations)

The first model examined was conceived in 1967 by Mathematica (*C-19*) for the Northeast Corridor Transportation Project (NECTP). The modal split function was a part of an econometric model that combined the freight demand estimation with the modal split function. It was referred to as "the macro-economic approach," which utilized a series of simultaneous equations in a multistage procedure to provide forecasts of T_{ijk}, the tonnage shipped from i to j by mode k. Time period and commodity type could also be incorporated into the model. The model began with a forecast of total demand in the study area for a specified time period and, through a sequence of disaggregations, estimated the flow of goods from particular origins and destinations by mode.

Type of model. Varies—a multistage approach that begins with a macro-aggregate forecast and, through a sequential procedure of simultaneous equations, ends with a micro-disaggregate estimate of freight flows.

General formulation. A system of simultaneous equations, whose form is not explicitly given.

Application of model. None.

Data requirements. Depend on the stage of analysis. The macro-aggregate level requires socioeconomic variables such as population, regional economic measures, and area characteristics. The micro-disaggregate estimates depend on various modal, commodity, and transport system factors. The precise data requirements were not addressed, but the report recommended multiple regression analysis as a way of determining which explanatory variables are significant. Data would have to be collected for various degrees of aggregation.

Evaluation. The "macro-economic approach" has not been developed to the degree necessary to allow a detailed appraisal of the methodology; however, a few observations can be made. First, utilization of a stepwise procedure enables the user to take maximum advantage of the available information. In other words, the estimation process will be carried out to the level allowable by the data set. If only general aggregate data are available, the model will produce only aggregate freight flow measures. Likewise, the more detailed the information, the more detailed the results. Second, an econometric model that can combine both demand estimation and mode choice in a continuous process has certain desirable attributes over two distinct and separately conceived models. The principal advantage is the compatibility of data and outputs of the demand model with the input to the mode choice model. Third, Mathematica recognized the need for disaggregate data (such as commodity and transport link characteristics) to forecast mode selection for explicit freight flows between two areas.

Inventory Theoristic Model

Mathematica (*C-19*) and Graves (*C-20*) both developed models based on inventory theory. Graves' "shipper preference" model was designed to estimate traffic diversion between two competing modes (rail and motor carrier) that resulted from proposed freight rate reductions. The computerized model was developed for the U.S. Bureau of the Budget using only data in ICC Docket 7027, a celebrated rate reduction case successfully defended by the eastern railroads. The model attempted to determine the size and kind of shipments necessary to re-supply depleting stock inventories due to estimates of future demand. Mode choice was based on relative shipping costs (the cost of replenishing inventory stock levels). A shipper's modal preference was determined by selecting the mode that minimized the total cost of maintaining adequate inventory levels.

Mathematica also proposed a model for estimating freight modal allocation through application of theoretical micro-economics and inventory theory. Through use of shippers' indifference curves (iso-cost equations), the model was able to predict the choice of mode by which a freight shipment would be transported.

Indifference curves are a way of diagramming a shipper's perceived trade-off between two or more variables. Mathematica chose speed and economy as the modal attributes that characterized a means of transportation, where speed and economy are reciprocals of transit time and freight rate, respectively. Figure C-1 shows how indifference curves are used to determine mode selection.

In Figure C-1, AA' and BB' are two individual shipper's indifference curves. The curves show that shipper B is more concerned with the stability of the freight rate charged than shipper A, due to the inelasticity demonstrated in his iso-cost curve. Points 1, 2, and 3 represent three alternative

TABLE C-2

FREIGHT MODAL SPLIT MODELS

MODEL TYPE	TITLE	REFERENCE	YEAR	DESCRIPTION
Macro-economic approach	—	Mathematica (*C-19*)	1967	Conceptual; not applied; simultaneous equations in stages (general-specific).
Inventory theoretic	(a) Shipper Preference Model	Graves (*C-20*)	1965	Based on inventory information and relative shipping costs.
	(b) Micro-Economic Approach	Vinod and Baumol (*C-19*)	1967	Variables: inventory costs, shipping costs, value of time, commodity type.
Regression analysis	(a) —	CONSAD (*C-48*)	1969	Variables: commodity, travel time, standard rate.
	(b) —	Bayliss (*C-49*)	1971	Variables: length of haul, relative freight pricing ratios, size of shipment.
	(c) —	Surti and Ebrahimi (*C-8*)	1972	Variables: size of shipment, distance, type of commodity, geographic area (not significant), plant size (marginal).
	(d) —	Tihansky (*C-22*)	1972	Variables: coal production and general economic measures (GNP, durable manufacturing index) to estimate rail freight volume.
	(e) —	Breitenbach (*C-23*)	1973	Freight distribution of modal shares by average distance of shipment.
	(f) —	A. D. Little (*C-21*)	1974	Strategic factors: length of haul, circuity factor, quantity moved, bulk or nonbulk character, commodity value, location of establishments, and mode seasonality factor to estimate domestic waterborne mode share.
Abstract mode (regression analysis)	(a) —	Quandt and Baumol (*C-19*)	1967	Variables: industrial character index, number of modes, transit time, transportation costs.
	(b) —	Penn St./Carnegie-Mellon Univ. (*C-50*)	1968	Variables: reliability, transport cost, distance, size of shipment, weight and number of shipments.
	(c) —	Herendeen (*C-13*)	1969	Variables: reliability, relative shipping cost, relative transit time, relative frequency of service between mode investigated compared with best service mode.
	(d) —	NBS (*C-42*)	1971	Variables: relative cost, relative transit time, empirically determined parameters.
	(e) —	Drake (*C-51*)	1972	Proposed for aggregate level of detail analysis.
	(f) —	TSC (*C-27*)	1975	Abstract commodity approach. Variables: weight of shipment, distance shipped, value per ton, rate charged for shipment.
	(g) —	CIGGT (*C-26*)	On-going	No information.
Linear programming	(a) —	Lockheed (*C-29*)	1968	Variables: shipper costs, commodity, distance, ownership, size of shipment. Constraints: route availability, capacity of links.
	(b) —	Roberts (*C-30*)	1971	Variables: link performance measures (waiting time, travel time, variability in travel time, probability of loss or damage), and transport cost and commodity cost attributes (cost of waiting, traveling, uncertainty, value, rate factor).
	(c) —	Tripp (*C-28*)	1972	Variables: commodity attributes (loading characteristics, susceptibility to loss or damage, volume of traffic, regularity of traffic, nature of equipment required, route characteristics), distance, operating characteristics (weather, geographical), traffic density. Constraints: demand satisfaction, capacity, logistic system.
	(d) —	Iowa State (*C-31*)	1973	Variables: shipping costs by vehicle type, handling charges, commodity, annual shipments, length of haul.
Discriminant analysis	(a) —	Miklius (*C-35*)	1969	Variables: average shipment weight, distance, plant employment.
	(b) —	Beuthe (*C-39*)	1970	Variables: travel time, rate, shipment weight, market price.
	(c) —	Antle and Haynes (*C-36*)	1971	Variables: annual tonnage, distance, average travel time, shipment size, rate, alternative rate, handling cost.
	(d) —	Sasaki (*C-37*)	1974	Variables: rate, shipment size, travel time, handling cost, distance, annual shipments.

TABLE C-2 (*continued*)

MODEL TYPE	TITLE	REFERENCE	YEAR	DESCRIPTION
	(e) —	U.S. Army (*C-38*)	1974	Variables: travel time, average shipment size, handling cost, distance.
	(f) —	Hartwig and Linton (*C-18*)	1974	Variables: travel time, rate, reliability, value of commodity.
	(g) —	CIGGT (*C-26*)	On-going	No information.
Logit	(a) —	Drake (*C-51*)	1972	Proposed for disaggregate analysis.
	(b) —	Kullman (*C-41*)	1973	Variables: tonnage, mileage, commodity value, relative freight rates, travel time, reliability.
	(c) —	Hartwig and Linton (*C-18*)	1974	Variables: transit time, inventory, storage requirements, reliability, safety stock, value of commodity, rate.
	(d) —	MIT (*C-52*)	1975	Proposed; not applied. Variables: some combination of attributes in categories of transport system level of service, commodity, market, shipper groupings; plus measures of frequency and average weight of shipments.
	(e) —	TSC (*C-27*)	1975	Variables: value per ton, weight of shipment, distance, rate.
	(f) —	CIGGT (*C-26*)	On-going	No information.
Probit	(a) —	Hartwig and Linton (*C-18*)	1974	Variables: travel time, rate, reliability, value of commodity.

means of transportation that display various modal characteristics. For example, point 2 is above and to the left of point 3, therefore the mode represented by point 2 will provide a cheaper and slower service than the mode represented by point 3. Likewise, the mode depicted by point 1 is both more expensive and slower than either of the other alternative means of transportation; hence, this mode will not be selected by either shipper, assuming all other factors equal. Point 1 is said to be dominated by points 2 and 3, and therefore can be eliminated as a likely choice of mode of transportation. Figure C-1 shows that mode selection for a particular shipper depends on how well a mode fulfills the desires of the shipper. Therefore, shipper A will prefer mode 3 over mode 2 because it exceeds the expectations set by his iso-cost curve, AA'. On the other hand, shipper B will select the opposite of shipper A to realize the maximum possible utility.

Indifference curves can be determined through an analysis utilizing inventory theory, where freight in transit is considered an essential element of the total variable cost of handling goods. Total variable cost in the Mathematica model equals the summation of direct shipping cost, plus in-transit carrying cost, plus ordering cost, plus recipient's inventory carrying cost, and a cost for preventing stock "outs" (safety stock cost). To determine the shape of the indifference curves, the total variable cost is held constant while a dependent variable, such as rate, is altered to determine the trade-off between the tested variable and one or more other variables.

Type of model. Mathematica's inventory theoretic model of modal choice is a micro, disaggregate approach that is based on classical micro-economics and inventory theory.

General formulation. In the Mathematica model, the optimal modal choice decision is the one that will minimize the shipper's expected total annual variable cost of handling, C. The general formula of the model is

$$C_{ijk} = r_k X_{ij} + u\, t_k X_{ij} + a/S + W S X_{ij}/2 + h\sqrt{(S + t_k)X_{ij}} \qquad \text{(C-5)}$$

in which

C_{ijk} = expected total annual variable cost of handling a consignment from origin i to destination j by mode k;

$r_k X_{ij}$ = direct shipping cost = (unit freight rate) × (quantity shipped per year);

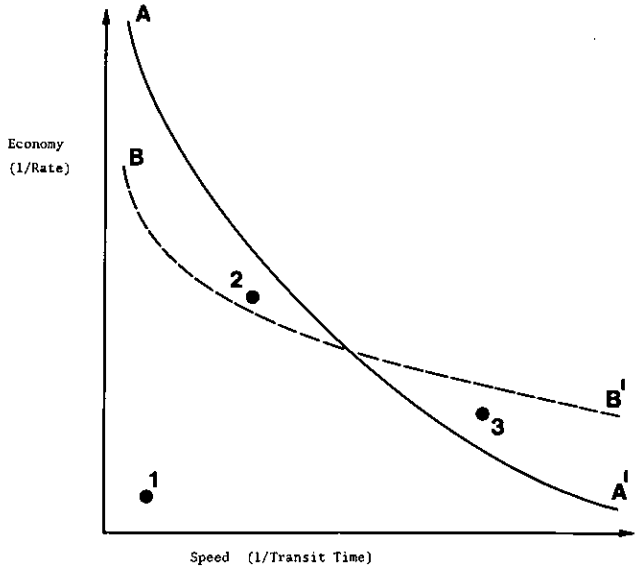

Figure C-1. Sample indifference curves.

$u\,t_k\,X_{ij}$ = total in-transit carrying cost
= (value of time)×(transit time)×(quantity shipped);

a = cost of ordering and processing per shipment;

S = interval between shipments;

$W\,S\,X_{ij}/2$ = recipients' inventory carrying cost
= (warehouse carrying cost per unit per year)×(average inventory level); and

$h\sqrt{(S+\bar{t}_k)X_{ij}}$ = safety stock cost.

Application of models. The "shipper preference" model was calibrated on data from ICC Docket 7027, Paint and Related Articles—Official Territory (1959) for consignments of 10 tons (9.07 metric tons) or more each. No application of the Mathematica model was cited.

Data requirements. The Mathematica model would require an extensive disaggregate data set, including information about recipients' demands at destination, inventory cost, ordering frequency, shipping costs, transit time, and a value of time associated with each commodity or consignment shipped. Baumol, the developer of the model, gave the following caveat about obtaining this data: "It is by no means clear that . . . the requisite data will be available or whose calculations are reasonably practicable" (*C-19*, p. 26).

Evaluation. Theoretically, the concept of utilizing microeconomics and inventory theory to determine modal choice has promise. It aids the modeler in clarifying some of the underlying relationships of why a shipper selects one means of transportation over another. The inventory theoretic approach to modal choice helps bring to light the following important observations pertaining to the mode selection decision-making process:

- Shippers act as discrete units; in other words, each shipper can perceive the significance of a certain variable affecting mode choice differently.
- Trade-off between time, cost, and dependability must be determined. Therefore, a determination of a dollar value of time must be made.
- Decisions of mode choice are not dependent solely on modal characteristics.

Although it is most desirable to have a model that can incorporate many of these important factors at a disaggregate level, there are three major drawbacks that will probably prohibit further development and/or application of this model. First, information required to run the model may not be available to state DOTs. Second, even if it were available, it is unlikely that all the necessary inventory data required by the model are being recorded. Third, the Mathematica report did not address the issue of aggregation of data. Can the shipping behavior of an individual firm be applicable to all firms that exhibit similar characteristics? It is for these reasons that such a "microeconomic approach" to freight modal choice is unrealistic at this time for statewide freight systems planning.

Regression Analysis (Linear Probability Model)

Several researchers (*C-8, C-21, C-22, C-23*) have employed the mathematically based procedure of regression analysis—simple regression or stepwise multiple regression—to examine freight modal choice. Multiple regression has been principally used to determine modal share (e.g., percent of traffic carried by rail) for various modal characteristics, or for other modal choice attributes. The process of stepwise regression selects and adds independent variables to the regression equation one at a time until the explanatory power of the model is deemed acceptable. The determinant that explains the most variation of the dependent variable (probability of mode selection) is selected first. Generally, the more variables in the equation the more statistically significant the equation is in accounting for the variance of the dependent variable. The regression equation is usually tested with a cross-sectional analysis of historical data.

Type of model. Regression analysis is a mathematically based procedure utilizing statistical measures to determine and predict the effects independent variables have on freight modal shares. The process fits a regression plane to empirical data by minimizing the squares of the residuals.

Regression analysis is not a model *per se;* however, it can be used as a method of carrying out an analysis of modal split. The kinds of independent and dependent variables employed by the technique determine the type of model. To illustrate, Surti and Ebrahimi (*C-8*) used *Census of Transportation* (*C-7*) data to develop an aggregate/tactical type of model, whereas A. D. Little (*C-21*) employed long-term elements in the regression equations to develop an aggregate/strategic model of modal choice.

General formulation. The general form of a partial or multiple regression equation (linear probability model) where there are n independent variables is

$$P_k\,(X_{ij}) = a + b_1\,X_1 + b_1\,X_2 + \ldots + b_n\,X_n + u \qquad \text{(C-6)}$$

in which

$P_k\,(X_{ij})$ = estimated magnitude of the dependent variable; in this case, the probability of selecting mode k for a consignment between origin i and destination j;
$X_1 \ldots X_n$ = independent variables;
$a, b_1 \ldots b_n$ = parameters;
u = error term.

Application of model. Surti and Ebrahimi (*C-8*) used regression analysis to predict the modal split of industrial traffic (highway and rail carriers). Three types of models (two curvilinear and one linear regression) were developed and calibrated against Bureau of the Census Commodity Transportation Survey (*C-24*) data. This study concluded that "only the multi-variable linear model is considered applicable and this model can have industrial and transportation applications. It could be used to predict industrial traffic . . . to assist firms in locating their plants, or to determine a carrier's appropriate share of tonnage produced in a region or by a plant" (*C-8*, p. 588).

A. D. Little (*C-21*) also employed regression analysis to forecast domestic waterborne freight movements in the

United States to the year 2000. A very significant correlation was found between the historically observed share of freight shipped by water and variables of a strategic (long-term) nature. The report concluded that the decision to ship by water is essentially determined by strategic elements, such as plant locations, rather than such commonly used tactical factors as transit time and reliability of service.

Data requirements. Surti and Ebrahimi (*C-8*) quantitatively studied *Census of Transportation* data to determine the relationship between the highway-rail distribution and the five independent variables of distance, weight, type of consignment, plant size, and geographical area. Each variable was selected on the basis of how well it met the criteria of independence, explanatory power of the dependent variable, and data availability. From the analysis it was concluded that the independent variables of size and distance of shipment by commodity group can satisfactorily explain the modal distribution between motor carrier and rail through the use of regression models. This implies that a separate model should be developed for each commodity type or group tested.

A. D. Little (*C-21*), through an analysis of waterborne freight movements, advanced the philosophical view that modal choice is chiefly affected by strategic factors. Their model incorporated both tactical and strategic variables that included length of haul, circuity, total tonnage transported, characteristics of the bulk commodity, commodity value, and location of producing establishment and consignee. Length of haul was determined to be the most significant factor influencing water mode's share of freight transported.

Evaluation of method. Regression analysis seems ideally suited for determining estimates of modal choice probabilities, from which total expected mode use can be calculated. The technique of stepwise regression has become a rather common method of determining statistical relationships between dependent and independent variables. This process has been computerized, therefore, freeing the modeler from the time-consuming task of manual manipulation of data that is so often required in the calibration and validation of an analytical model.

Regression models are descriptive; that is, they attempt to explain modal selection behavior through mathematical relationships developed from a cross-sectional analysis of historical data. Therefore, models of this type are built on the assumption that a shippers' behavior will remain the same over time.

The net effect of assuming the status quo in an analysis of mode choice is negligible as long as the shipper's perceived values remain about the same over the study period.

The principle advantages of using regression formulations are as follows:

- It allows the modeler to investigate the explanatory power of independent variables in determining modal share.
- Inclusion of time-invariant and time-dependent variables is permitted in regression models.
- Variable independence can be tested using this type of technique.
- The ranking of independent modal selection attributes is a standard output of the stepwise multiple regression process.
- The technique of regression analysis can be totally computerized.
- The process is simple to understand and apply.
- The process is evaluated principally on statistical measures, such as the *F*-value test.
- The regression formulation seems preferable for situations where fractional modal splits occur, such as would be the case with certain pairs of regional aggregates.

The last statement seems to summarize the true worth of using the regression technique for modal selection analysis—in one word, flexibility. Regression analysis has been used for freight demand forecasts, predicting modal choice, and various sensitivity analyses. Models have been developed from an aggregate data base, such as the A. D. Little computerized modal share model described previously, and also models based on disaggregate data, such as the abstract mode model discussed later in this section. Regression analysis will undoubtedly find a role in statewide freight transportation planning, especially modal selection studies. However, there are several statistical problems associated with using a linear probability model. The most significant is the problem of unbounded probability; that is, the estimated conditional probability may produce values greater than 1 or less than 0. For this reason, many researchers have selected logit or probit models instead of linear probability models, which bound the estimated probability of mode choice always within the range of 0 to 1.

Abstract Mode Approach

The abstract mode technique describes a mode by its characteristics rather than its name. Although this approach was initially advanced by Mathematica for the estimation of passenger demand for the Northeast Corridor Transportation Project (*C-25*), the same procedure may be directly used for work in freight demand analysis. The abstract mode approach proposed by Mathematica (*C-19*) predicts the demand, by mode, for freight transportation between specified origin-destination pairs. The pure abstract mode model views demand for freight along any link in a network and a particular (abstract) mode as dependent on the characteristics of that mode and on key commodity attributes. This approach handles the freight generation, distribution, and modal split elements as one task.

Herendeen (*C-13*) proposed a modified version of this model that was later adopted for use in the Department of Transportation/National Bureau of Standards multimodal network model. This model is very similar in mathematical formulation to the original but differs in that it deals only with the task of estimation of mode choice.

In Canada, Turner (*C-26*) recently completed a comprehensive empirical study on freight modal choice procedures. This study concluded that the abstract mode technique is the method best suited for explaining macro-level mode choice decisions under existing data availability limitations. As far as can be ascertained, this empirical work is the first actual application of the abstract mode model to available data.

Type of model. Inasmuch as the abstract mode concept addresses the problem of predicting the mode of transporta-

tion between specified origin-destination pairs, this type of model can best be classified as microscopic in nature, and would require a disaggregate data base. Advocates of the abstract mode approach seem to agree that multiple regression analysis is the best technique for developing the model. In this situation, regression analysis allows all relevant variables to be considered and determines the relative importance of each independent variable.

General formulation. The general form of the model proposed by Herendeen (*C-13*) is

$$P_k(X_{ij}) = \alpha_o R_k^{\alpha 1} C_k^{\alpha 2} T_k^{\alpha 3} F_k^{\alpha 4} \qquad \text{(C-7)}$$

with the constraint

$$\sum_k P_k (X_{ij}) = 100 \qquad \text{(C-8)}$$

in which

$P_k (X_{ij})$ = percentage of X_{ijk} that will be shipped by mode k;

R_k = reliability of mode k;

C_k = relative cost by mode k

$$= \left(\frac{\text{lowest rate by all available modes}}{\text{rate by mode k}} \right);$$

T_k = relative transit time by mode k

$$= \left(\frac{\text{lowest time by all available modes}}{\text{time by mode k}} \right);$$

F_k = relative frequency of service

$$= \left(\frac{\text{frequency of service by mode k}}{\text{best frequency of service}} \right);$$

α_o = coefficient to be determined by the regression analysis; and

$\alpha_1, \alpha_2, \alpha_3, \alpha_4$ = exponents to be determined by the regression analysis.

Application of model. Herendeen (*C-13*) suggests several methods of applying the model after calibration. One method is as follows:

1. Obtain total annual traffic demand estimates by commodity for each origin-destination pair. These flows should conform with the output of a freight demand model and be in the form of X_{ijh}, expressed in tons of goods h to be shipped from origin i to destination j in one year.
2. Obtain average size of shipment by dividing annual demand, X_{ijh}, by the number of shipments made within the year, N_{ijh}.
3. Develop an equation that determines the rate per ton by commodity for all available modes as a function of distance and shipment size. Distance for origin-destination pairs can be obtained from actual routing data or from a traffic assignment model.
4. Determine relative transportation costs by taking the lowest cost of all available modes as the common numerator and the costs of each mode as denominators.
5. Relative transit times estimates are determined using a procedure similar to that described in Step 4.
6. Measures of relative service frequencies and reliability would then be calculated.
7. For each mode k, $P_k(X_{ijh})$, will be determined with the constraint that the sum of all modes percentage of X_{ijh} equals 100 percent.
8. Amount of commodity h shipped between origin i and destination j by mode k_{ijh} will then be determined by multiplying X_{ijh} by $P_k(C_{ijh})/100$.
9. The above process would be repeated for each origin-destination pair and for each commodity classification tested.

Herendeen's efforts to calibrate the model were hampered by limited availability of data. Preliminary testing of the model was restricted to just two modes (highway freight and rail freight), five commodity groups (all manufactured goods), and three independent variables (relative costs, relative transit time, and reliability). Calibration of the model was based on *1963 Census of Transportation* (*C-7*) data.

Turner (*C-26*) was fortunate to have at his disposal a large bank of disaggregate data on 1970 freight movements in Canada via truck, rail, and ship, which was collected for the Canadian Freight Transport Model under the sponsorship of the Canadian Institute of Guided Ground Transportation. The data consisted essentially of records of individual freight consignments. Information contained on each record included mode of transportation, origin and destination terminals, distance shipped, transit time, size and commodity group of shipment, and a measure of the unit value of commodity shipped. Preliminary testing of the model was restricted to a small sample of selected freight movements that were thought to exhibit competitive modal characteristics. Lack of information on reliability of service measures caused some problems in the calibration of the model.

Data requirements. Herendeen identified the following eight variables that are significantly related to the freight modal split task, based on a review of related literature and an awareness of the shipper decision-making process:

- Cost of the transportation service to the shipper.
- Quality of service provided by carriers.
- Type of commodity shipped.
- Size of shipment.
- Distance shipped.
- Time spent in transit.
- Reliability regarding delivery schedules.
- Frequency of service.

He noted that, because of the expense of data collection, a careful analysis of all possible variables is required to uncover any interrelationships (correlations) that would allow a reduction in the total number of independent variables. To illustrate, weight and distance of shipment are interrelated with transport cost. Distance affects the carrier's variable costs, which increase with length of haul, thus the rate charged becomes a function of distance. The weight of shipment can also affect costs, as demonstrated in the complex rate structures of each mode. The effect of distance and weight on rates is not linear; that is, costs do not increase in direct proportion to distance or size but

increase at a decreasing rate. Based on this rationale, Herendeen concluded that transport cost can be substituted in the model for the variables distance and weight of shipment.

A similar examination of each variable led to the reduction of variables from eight to five. The independent variables used in the model were commodity type, relative costs, relative service frequencies, relative transit times, and reliability. Commodity type was not entered as an independent variable in the model because the relative ranking of variables would be different for different commodity groups. To illustrate, transit time and reliability of service are much more critical to shippers of perishable commodities than to shippers of bulk, low-value goods. Therefore, it would be necessary to calibrate a separate regression analysis for each commodity classification studied. This means that if 25 groupings of commodities are used, there would be 25 separately developed models for predicting modal split. This is clearly undesirable.

Herendeen attempted to calibrate the model with limited success. Data regarding frequency of service were not available, and therefore were not included in the preliminary testing of the model. Several sources were used to supplement the *1963 Census of Transportation* (*C-7*) information to obtain the necessary data. Preliminary testing was limited to only five commodity groups as defined by the Standard Transportation Commodity Classification (STCC) with data aggregated to the national level.

Evaluation of method. The abstract mode approach to freight modal split analysis offers several unique advantages. Using this approach a mode can be described by its characteristics instead of its name, allowing for examination of new transportation technology or new modes by merely specifying a few of the important modal attributes without referring to its physical form. This modal selection process can evaluate the sensitivity of the mode split decision to changes in a mode's travel time or cost. The information is useful for evaluating the impacts of policies, such as revisions of the freight rate structure or provision of capital investment subsidies for updating and improving a particular means of transportation. Also, the model has been structured in a mathematical form that is familiar to most. Multiple regression analysis has been used with acceptable results in numerous studies related to other aspects of transportation planning, such as trip generation and demand estimation.

There are three major drawbacks of the abstract mode concept in its present form. One is the lack of consideration given to commodity type. Because the model contains no commodity attributes and because Herendeen's efforts indicate the presence of commodity-specific influences, it would be necessary to calibrate a model for each commodity type or grouping studied. Although this is undesirable, it may be the only practical way of modeling freight modal choices. Turner has tried to add commodity characteristics to the model as dummy variables to help eliminate this problem.

The Transportation Systems Center in Cambridge, Mass. recently tested two types of modal split models (*C-27*), one of which has been classified as an abstract commodity approach. Based on a premise similar to that of the abstract mode approach, the abstract commodity approach can determine mode split decisions from commodity characteristics. The model used weight of shipment, distance shipped, value per ton, and rates charged for shipment as independent variables.

The second disadvantage involved the problem of defining the "best" mode. What is the "best" mode of transportation? To illustrate, the rail rate per ton charged for a large shipment of a commodity may be cheaper than the rate per ton charged for truck transport, but the reverse may be true for smaller shipments. Care must be exhibited to avoid including such ambiguities in the model.

The third problem area involved inter-modal effects. There is no apparent way of affecting the modal share of traffic carried by the "best" mode. The model is formulated in such a fashion that only changes in the "best" mode will affect that mode's share of the market—changes in an inferior mode, such as lower rates, will still not alter the traffic moved by the "best" mode.

Linear Programming

Several researchers (*C-27, C-29, C-30, C-31*) have investigated the use of operations research techniques as a means of describing and replicating the mode choice selection process of shippers. Linear programming is a technique that optimizes systems performance through mathematical solutions. The linear programming formulation for the shipper's selection among alternative modes assumes that mode choice is a constrained minimization problem. A linear programming model is comprised of an objective function and a set of constraints that bound the solution set.

In a modal split analysis, the objective function is usually a cost equation minimized. This transport cost equation is not limited to the actual tariff paid by the shipper, but may also include the cost to the shipper of less easily quantifiable elements—such as inventory costs, ownership costs (the shipper's cost of having capital tied up in shipment), cost of spoilage, and loss and damage costs—as a function of the amount of time the shipment is in transit. Each mode of transportation has associated with it different cost attributes, which are reflected in the objective function. The process selects the mode of shipment that provides the lowest cost option, given that a set of demand and systems constraints are all met satisfactorily.

To illustrate how linear programming can be applied to an analysis of freight modal selection, the research effort of Tripp (*C-28*), which was concerned with the economic consequences of establishing multimodal transportation companies (*C-28*, p. xi) is examined in greater detail in the following.

Type of model. Linear programming is a mathematically based procedure that has been used primarily as an optimizing system technique. The modal split model developed by Tripp is classified as a micro-aggregate type of model.

General formulation. The linear programming formulation developed by Tripp (*C-28*) for determining the shipper's selection among alternative modes is:

Objective function

$$\text{Min } Z = \Sigma_i \Sigma_j [r_{1ij} T_{1ij} + r_{2ij} T_{2ij} + r_{3ij} T_{3ij} + r_{4ij} T_{4ij}] \quad \text{(C-9)}$$

Subject to:

1. Demand satisfaction

$$T_{1ij} + T_{2ij} + T_{3ij} + T_{4ij} = X_{ij} \text{ for all i and j} \quad \text{(C-10)}$$

2. Capacity constraints

$$T_{1ij} + T_{2ij} \leq Y_{1ij} + Y_{2ij} \text{ for all i and j} \quad \text{(C-11)}$$

$$\Sigma_i \Sigma_j T_{3ij} \leq F_R \quad \text{(C-12)}$$

$$\Sigma_i \Sigma_j T_{2ij} \leq F_R - \Sigma_i \Sigma_j T_{3ij} \quad \text{(C-13)}$$

$$T_{3ij} \leq Y_{3ij} \text{ for all i and j} \quad \text{(C-14)}$$

$$T_{4ij} \leq Y_{4ij} \text{ for all i and j} \quad \text{(C-15)}$$

3. Logistics system constraints

$$T_{1ij} + T_{2ij} + T_{3ij} \geq W_{ij} \text{ for all i and j} \quad \text{(C-16)}$$

$$T_{4ij} \geq U_{ij} \text{ for all i and j} \quad \text{(C-17)}$$

$$T_{1ij} \geq Z_{ij} \text{ for all i and j} \quad \text{(C-18)}$$

$$X_{ijk} \geq 0 \quad \text{(C-19)}$$

in which

T_{ijk} = amount of freight moved from origin i to destination j by mode k; k = 1 when the movement is by common carrier truck, 2 and 3 when the movement is by alternative TOFC/COFC plans, and 4 when the movement is by rail;
r_{ijk} = tariff, as a rate per hundredweight, charged by a carrier for moving the product between i and j by mode k;
X_{ij} = demand for transportation service between origin i and destination j;
Y_{ijk} = capacity, in hundredweight, allocated by mode k for movements between i and j;
F_R = amount of flatcar capacity the railroad has available for both types of piggyback movements;
W_{ij} = amount of traffic that must be loaded into truck trailers at i for movement to j;
U_{ij} = amount of freight that must be shipped by rail due to some shippers' logistics constraints between i and j; and
Z_{ij} = quantity of product that must be shipped by truck over-the-road between i and j; again this is a predetermined logistical constraint set by the shippers.

Application of model. Tripp (*C-28*) used the technique of linear programming in predicting the shippers' modal selection to provide necessary inputs for examining the economic consequences of establishing multimodal transportation companies.

Truck, piggyback, and rail traffic estimates were made under each organizational approach; that is, a multi-mode transportation company versus single-mode carriers. A mathematical simulation model was developed to analyze two hypothetical situations to determine what effects various combinations of parameters or test factors would have on a transportation company formed from single-modal carriers.

To simplify the analysis, Tripp limited the hypothetical transportation system considered to two modes, highway and rail, including piggyback movements. Also, the analysis was restricted to one product with average commodity characteristics which is subject to intermodal competition between a small number of origin-destination pairs for a single time period.

Data requirements. The data used in Tripp's study were hypothetical. The model required both exogenous and endogenous types of variables. "Exogenous variables are the independent or input variables of the model and are assumed to have been predetermined and given independently of the system modeled. Endogenous variables (decision variables) are the dependent or output variables of the system and are generated from the interaction of the systems (model's) operating characteristics" (*C-28*, p. 10).

Tripp's efforts were based on the hypothesis that a shipper and a carrier will always try to minimize their total cost of shipping a consignment between two points given that the method of transportation does not violate the shipper's logistics constraints.

Variables mentioned that affect the cost of movement are:

1. Exogenous variables:
   (a) Uncontrollable commodity characteristics:
   Loading characteristics.
   Susceptibility to loss and damage.
   Volume of traffic.
   Regularity of traffic.
   Nature of equipment required.
   (b) Uncontrollable route characteristics:
   Distance.
   Operating conditions (geographical and weather factors).
   Traffic density.
   (c) Uncontrollable demand for transportation:
   Amount of traffic captive to a specific means of transportation.
   (d) Controllable exogenous variables:
   Carriers' scheduling operations.
2. Endogenous variables (decision variables):
   (a) Quantity shipped.
   (b) System capacity constraints.
   (c) Tariff charged to shippers.
   (d) Commodity.
   (e) Route.
   (f) Competition.

Data on cost of moving goods were required and were composed of a profit margin, fixed and/or common costs, and out-of-pocket costs. Out-of-pocket costs were subdivided into four component costs: line-haul costs, pick-up and delivery costs, terminal costs, and billing costs.

Evaluation of method. Tripp recognized that many variables could affect the shippers' modal selection decision policy. These parameters may be classified as environmen-

tal, commodity, and route factors. The mathematical simulation model developed by Tripp (*C-28*) unfortunately only included parameters related to route. Commodity factors were not addressed in this study for the sake of simplicity. Validation of the model results with actual data was not possible due to the hypothetical nature of the study and lack of information.

Linear programming models view the modal selection decision process as a constrained minimization problem that is bounded by shippers' logistics constraints. This type of model will always select the mode of transportation with the lowest cost, given that the system constraints are met. The major drawbacks with using linear programming models are: (1) commodity attributes are not included; (2) the inclusion of unquantitative factors, such as dependability of service, is difficult; and (3) the accurate specification of system constraints is questionable.

The principal advantages of linear programming include a well-documented methodology that (1) is computerized and (2) enables the user to restrict the modal options available to the shipper. This constraint mechanism is a key element in the linear programming process. It allows the modeler to specify modal preferences. Freight flows are similar to passenger movements; some movements are captive to a specific mode and some are not. Linear programming provides the means of describing this observed modal characteristic as part of the model itself.

Discriminant Analysis

Discriminant analysis is a multivariate statistical tool that has been used to classify freight traffic among different modes of transportation. A model based on this approach can assign or classify a consignment to one of several modes with a minimum of error on the basis of specified characteristics of the consignment. This is accomplished through use of a linear discriminant function that is comprised of a linear combination of explanatory variables.

Figure C-2 shows graphically the intrinsic properties of the discriminant function method of estimating modal choice. If the frequency distribution of the shipper's modal-choice characteristics is known for each mode of transportation, for a given consignment a disutility value, Z, can be computed and the probable mode of transportation predicted. If the computed value of Z is greater than Z^1, mode 2 is likely to be selected; if Z is less than Z^1, mode 1 will probably be selected. In Figure C-2, the two distributions are obviously separated. However, there could exist an area of misclassification where the tails of each distribution overlap, as indicated by the shaded area. Therefore, the ideal discriminant function is the one that minimizes the number of misclassifications of consignments to their observed means of transport.

Type of model. Discriminant analysis was designed to function as a classification model. This statistical analysis technique is ideally suited for binary modal choice analysis but can be applied to more modes if needed. Discriminant analysis is usually grouped along with probit and logit analyses in the general category of disaggregate, behavioral binary modal choice models.

General formulation. The discriminant function for a two-mode choice can be written

$$Z_{ij} = [X - \tfrac{1}{2}\ (\overline{X}_i - \overline{X}_j)]\ S^{-1}\ (\overline{X}_i - \overline{X}_j) \qquad \text{(C-20)}$$

in which

Z_{ij} = linear discriminant function value;
X = the vector of characteristics of a given mode and/or commodity to be used to categorize a consignment as using mode i or mode j;
$\overline{X}_i, \overline{X}_j$ = the vector of mean characteristics of all shipments that use i and j, respectively;
S^{-1} = the inverse of the estimated variance-covariance matrix of X characteristics of a mode and/or commodity within each mode; and
$[\,]$ = the transpose of the vector expression within the brackets.

If there are only two modes, i and j, the discriminant function can classify a consignment in accordance with the following rule: if $Z_{ij} \geq 0$, the consignment is classified as a user of mode i; otherwise, the consignment is classified as a user of mode j.

A number of methods can be used to test the statistical significance of the discriminant function. The F-statistic can be used to test if the sample size is adequate. A "confusion matrix" can determine the ability of the discriminant function to classify correctly. The "confusion matrix" displays in matrix form the number of correct classifications and the number of misclassifications. Chi-square tests indicate if the differences in modes of transportation are significantly different.

Two critical assumptions must be made when using discriminant analysis: (1) the distributions of the variables are multi-variant normal and (2) the variance-covariance matrices of the two sets of variables are the same. Stopher (*C-33*) and Warren (*C-34*) have suggested a variation of the aforementioned methodology that transforms the linear discriminant function into a probability function.

Application of model. Several investigators (*C-18, C-35, C-36, C-37, C-38, C-39*) have employed the technique of discriminant analysis to examine freight modal choice.

Miklius (*C-35*) tested the feasibility of using linear discriminant functions to estimate the allocation of freight

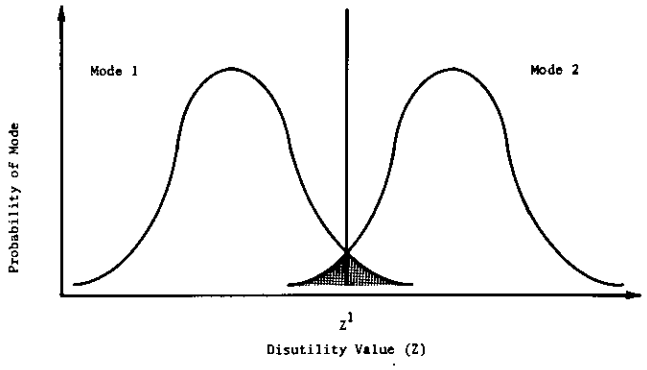

Figure C-2. Discriminant function method.

traffic between different modes of transportation. The mode choice examined was rail vs truck. The model was calibrated on aggregated freight data for one commodity, frozen vegetables, from the *1963 Census of Transportation* (*C-7*). The discriminant function formulated for predicting individual mode choice decisions was:

$$Z = 0.0053\,X_1 + 0.00013\,X_2 - 0.00017\,X_3 - 0.00004\,X_4 \quad \text{(C-21)}$$

in which:

Z = probability of making a rail shipment;
X_1 = shipment weight, in 100,000 lb;
X_2 = distance, in 100 air-miles; and
X_3, X_4 = dummy variables for employment size of the originating plant as a proxy measure for rail availability.

Statistically, the variables weight and distance were found to be significant, whereas the plant size has little, if any, significance in connection with this study. This work was important because it was one of the first attempts to demonstrate application of discriminant analysis to freight mode choice modeling. Miklius' study was not without its limitations. He cautions about application of his model to other commodities because the model was based on only one commodity. He also points out that data requirements are an important limiting factor to the accuracy of the discriminant model. Results of the study were moderately successful in predicting mode choice accurately.

Hartwig and Linton (*C-18*) also experimented with discriminant analysis to model individual shipper's mode choice between truck and rail. Using a disaggregate data base in the form of audit copies of freight bills from a shipper of consumer durable household manufactured goods, they attempted to improve the precision of the discriminant model. Their conclusions were that the discriminant model was quite sensitive to data changes and that logit and probit analysis appeared to be more stable and better classifiers of individual freight shipments than discriminant analysis. In the model forms tested, modal cost and commodity value were found to be important (statistically significant) in a shipper's mode choice. Transit time and reliability were not statistically significant variables in their discriminant formulation; this they hypothesized was due to individual processing of the data. They concluded that further testing of discriminant analysis was warranted on a wider variety of commodities, for a larger number of different shippers, and for different degrees of data aggregation, if the data could be gathered.

Three other researchers—Antle and Haynes (*C-36*), Sasaki (*C-37*), and U.S. Army Corps of Engineers (*C-38*)—have also applied discriminant analysis principally to estimating barge transportation demand. In all cases, the models developed were calibrated on a small data set and utilized a series of computer programs for displaying the results of the discriminant function. The most recent of the three studies is by the U.S. Army Corps of Engineers. Their work, which was an expansion of Antle and Haynes' efforts, covered a wider geographical sample area (Arkansas River area), more modes (barge/rail/truck), and more commodity groups (six 2-digit SIC commodities) than that of their predecessor. After preliminary testing, the following conclusions on discriminant analyses were made:

- Development of a (disaggregate) data base is difficult.
- Although the model was tested on six variables (travel time, shipment size, rate, annual shipments, handling cost, and distance), fewer numbers of variables could be used and still produce acceptable discriminant results.
- The rank order of variables can be different, depending on the commodity group tested.
- The discriminant function does have the ability to correctly classify individual shipment by mode of transportation.
- A single aggregate group discriminant function probably would not select the correct mode for different commodity groups.
- Computer use in discriminant analysis appears to be a very efficient way of analyzing data.
- Discriminant analysis models appear to be a relevant tool of analysis for use in many water resource projects.

Data requirements. Of the previously mentioned studies, only Miklius (*C-35*) applied discriminant analysis using aggregated freight data—1,529 shipment records for frozen vegetables from the *1963 Census of Transportation* (*C-7*). Model data requirements were shipment weight, distance, and employment size of the originating plant. Although the performance estimates of Miklius' discriminant model were only fair, Miklius still concluded that discriminant functions appear to be a better multi-purpose estimator function than any of the freight rate functions (simple linear regression models) that he could develop.

Hartwig and Linton (*C-18*) attempted to obtain disaggregate data from both carriers and shippers. Due to data collection problems, their data gathering efforts culminated in obtaining disaggregated data from just one source, that of a manufacturer of household consumer durable goods. This data base consisted of 1,213 audit copies of freight waybills for both rail and truck shipments of consumer durables. These waybills included the following information:

- Mode of transportation (truck or rail).
- Shipment origin and destination.
- Date shipped and received.
- Freight rate and total freight tariff.
- Weight of shipment.
- Routing information.
- Type and number of pieces of the commodity being shipped.

From this information they were able to determine distance, transit time, modal freight changes, value of the commodity shipped and a measure of reliability (the difference in the standard deviation of the transit time distributions). These variables, which were believed to be important to shippers' mode choice, were selected for use in testing their model.

In the barge transportation studies (*C-36, C-37, C-38*), shipper surveys were used to collect data. Relatively few firms were surveyed in each study. The largest data base obtained contained 194 individual observations (commodity

movements). Each observation used included the following six characteristics: annual tonnage shipped, average shipment size, transit time per shipment, tariff, distance, and handling cost.

Evaluation of method. Discriminant analysis is a statistical technique that has been used to model the individual firm's mode selection process by constructing linear functions that describe the characteristics of each mode of transportation. This disaggregate type of model can incorporate monetary as well as nonmonetary factors to produce near-perfect internal allocations of selected commodity movements among modes. To date, discriminant analysis has not been used extensively due to the scarcity of data at the required level of detail. Nonetheless, the aforementioned studies (*C-18, C-35-C-39*) have demonstrated that discriminant analysis can be applied to detailed analysis of freight modal choice. However, three major shortcomings prevent wider use of discriminant analysis for micro-level or macro-level policy analysis, as follows:

- General lack of commodity attributes within the model, which means that a separate model would have to be calibrated for each commodity group studied if the desired model is to be related to particular goods.
- The model's sensitivity to data change. Hartwig and Linton concluded that "the discriminant formulation is quite sensitive to data changes" (*C-18*, p. 91).
- The problem of gathering sufficient quality and quantity of disaggregate data necessary to calibrate, test, and apply discriminant formulations to freight modal split analysis.

Logit Analysis

Logit analysis, originating in the field of biometrics, is a statistical technique that recently has been used extensively in the field of disaggregate passenger travel demand modeling. Detailed discussion of the logit form and disaggregate modeling is given by Ben-Akiva (*C-40*). The multinomial logit model has two important and essential characteristics. The first is that the estimated probability of mode choice always lies within the range of 0 to 1, eliminating the unbounded probability problem inherent in using linear probability functions. The second logit characteristic is that the sum of the probabilities of the choice of each of the mode alternatives is equal to 1. Figure C-3 shows the logit formulation for a binary choice model.

Type of model. As Figure C-3 shows, the logistic model is a nonlinear model that is able to fit a linear probability function to a logistic growth curve that is very similar to the probit sigmoidal response curve described in the next section.

This logit form for disaggregate modeling was chosen for review because of its demonstrated reasonable explanatory powers to predict the probability that the shipper will select a specified means of transportation from a set of alternative modes. Freight mode choice models of the logit form have been used to predict the truck-rail modal split as a function of modal and commodity characteristics using aggregate data by Kullman (*C-41*), and using disaggregate data by Hartwig and Linton (*C-18*).

General formulation. The logit model, in its multinomial form, can be written

$$P_k(X) = \frac{e^{U(X)}}{1 + e^{U(X)}} \qquad \text{(C-22)}$$

in which

$P_k(X)$ = the probability of a shipper choosing mode k out of the full set of mode alternatives available to him.

$$U(X) = x_0 + x_1 X_1 + \ldots + x_n X_n \qquad \text{(C-23)}$$

X_1, X_n = independent variables, expressed as differences; and

x_n = coefficients of X_n

therefore, if $P_k(X)$ is the probability of choosing mode k, the probability of not choosing mode k is $1 - P_k(X)$, in which

$$1 - P_k(X) = 1/(1 + e^{U(X)}) \qquad \text{(C-24)}$$

The logit transformation of the linear probability function is written

$$\log_e \left(\frac{P_k(X)}{1 - P_k(X)} \right) = x_0 + x_1 X_1 + \ldots + x_n X_n \qquad \text{(C-25)}$$

in which the left-side term is called the logit.

Several procedures lend themselves best to this method for estimating the values of the coefficients $(x_0, x_1 \ldots x_n)$; among these are the methods of maximum likelihood estimation and the minimum X^2 method. A description of the method for estimating the likelihood function can be found in Hartwig and Linton (*C-18*).

Application of model. Several investigators (*C-18, C-26, C-27, C-41, C-42*) have designed freight modal split models using the logit formulation, as follows:

- Kullman (*C-41*) to predict rail-truck split for specific city pairs and commodity groups.
- Hartwig and Linton (*C-18*) to model an individual

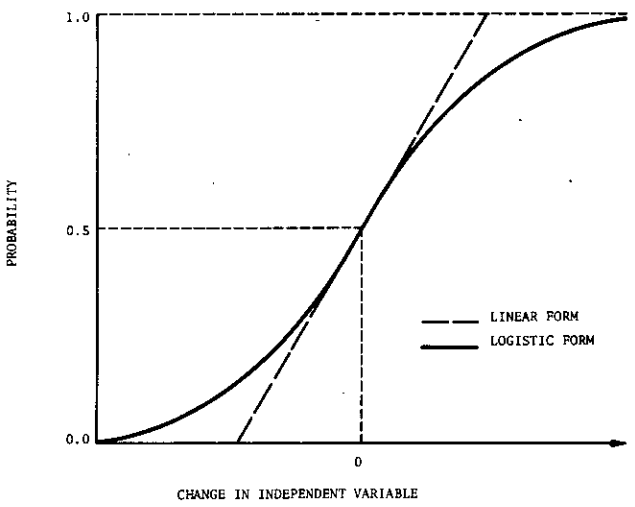

Figure C-3. Logit model.

shipper's mode choice between rail and truck for a single commodity.

- Turner (*C-26*) to test the explanatory and prediction powers of the logit model compared with those of a discriminant function and abstract mode approach for determining mode choice probabilities between rail and truck for selected freight shipments in Canada in 1972.
- Tucker (*C-27*) expanded on Kullman's work to test if it is possible to achieve better results by experimenting with new ways of aggregating commodity groups and refinement of the mathematical formulation used.

Kullman used a binary logit model with aggregated census data to estimate market shares for rail and truck as a function of factors that were believed to influence freight modal choice. The logit formulation was tested under a variety of aggregations (both commodity and geographical) and a number of different variable combinations to determine which combination would produce the best model results. Commodities were grouped by STCC 2-, 3-, 4-, and 5-digit levels and also by value (low, medium, high). Geographic aggregations ranged from the country as a whole to shipments between specific SMSA pairs. The variables tested in the different model forms included: variables not under carrier controls (value per ton of commodity, mileage, and annual tonnage) and variables under carrier control (freight rates, transit time, and reliability).

The model with the best results was obtained with a modified data sample using 3-digit STCC commodity data for specific SMSA pairs, and using commodity value, mileage, and annual tonnage as independent variables. The form of this model was

$$\ln\left(\frac{\text{Rail share}}{\text{Truck share}}\right) = -13.13 - 0.941 \ln\left(\frac{\$/\text{ton}}{1{,}000}\right) + 0.888 \ln\left(\frac{\text{tons}}{10{,}000}\right) + 1.52 \ln\left(\frac{\text{miles}}{100}\right) \quad \text{(C-26)}$$

for which $R^2 = 0.337$.

All coefficients are significant at 95 percent confidence level.

Hartwig and Linton (*C-18*) in their study used disaggregate individual shipment data from a single source for a specific commodity group (consumer durable household manufactured goods) to estimate truck-rail modal split. Using differences in truck and rail transit time, freight costs, and reliability with value of commodity as the independent variables, their empirical results showed that the logit formulation was an excellent internal predictor, but cautioned against general application of the model to other data sets. In their analysis, relative cost, relative reliability, and commodity value were all determined to be statistically significant to modal choice. The logit formulation in their study was preferred over the use of either the probit or discriminant analysis models developed.

Tucker et al. (*C-27*) were able to achieve much better empirical results (R^2 ranging from 0.48 to 0.63) using a modified version of Kullman's logit model, than Kullman's best R^2 ($= 0.34$) with aggregated data similar to that used by Kullman. Their model included characteristics of weight of shipment, distance shipped, commodity value, and freight rate changes.

Data requirements. Kullman's major data source was the *Census of Transportation* (*C-7*). He developed some crude approximations for estimating average transit time. To determine average truck time, he assumed a truck could travel for 10 hours a day at an average of 45 mph. Freight costs were calculated from generalized rate estimating regression equations. Rail rate equations were based on *Rail Carload Waybill Statistics* (*C-43*), whereas truck rates were based on rate data from Morton's (*C-44*) waybill study. Kullman was unable to determine a suitable index for reliability because of difficulties stemming from data aggregation.

Hartwig and Linton (*C-18*) were able to collect freight bills for both rail and truck from a single source containing information for a particular commodity class.

The major source of data used by Tucker et al. at the Transportation Systems Center was the *1972 Census of Transportation* (*C-7*). The commodity value per ton was based principally on Bureau of Labor Statistics wholesale price data, supplemented from a variety of other sources. Average freight rates were developed for motor carriers (common and private), railroad carriers, and air carriers, summarized by commodity and mileage blocks. A description of the methodology used to develop these rates is given in Appendix 3 of TSC study on intercity freight mode choice (*C-27*). The major data sources used in the development of modal rates were:

1. Truck rates:
   (a) ICC, National Motor Freight Classification (NMFC), which presents motor freight commodity rates in terms of truckload and less-than-truckload class rates.
   (b) Trinc Transportation Consultants' *Blue Book* (*C-45*), 1973 edition, which lists average commodity revenue in cents/ton-mile.
2. Rail rates:
   (a) Computer sample of 1972 Railroad Waybill Statistics summarized by commodity and mileage blocks.
3. Air rates:
   (a) Unpublished report of air carrier revenues by an airframe manufacturer, dated 1970.

Transit time and reliability variables were omitted from their analysis due to the difficulty in calculating these variables at such an aggregate level with census data.

Evaluation of method. Kullman (*C-41*) used a binary logit model to determine the feasibility of using disaggregate models for freight modal choice. He concluded that (1) the accuracy of disaggregate models is limited due to the high sampling variability of the existing data, and (2) the aggregation of data can lower the variation among observations of certain variables, such as travel time reliability, to a point where its inclusion in the model is insignificant. Kullman took a very pessimistic view of the progress that can be expected in future attempts to develop modal split models which achieve high predictive powers.

This position was based on the belief that adequate data for comprehensive disaggregate modeling will never become available, even for detailed analysis at the micro-level, due to the difficulty of achieving shipper cooperation in obtaining the data, the diversity exhibited in the freight market, the unpredictability of shipper behavior, and the high cost associated with obtaining the data.

The work by Hartwig and Linton (*C-18*) also demonstrated that the selection of independent variables for disaggregate modeling is very dependent on data limitations, the characteristics of the shipper, and the characterisics of the consignment being transported. They noted that freight carriers generally do not record the needed data for disaggregate modeling and shippers are reluctant to release their records because they consider this information to be proprietary. They suggested that aggregation of data may be a way of circumventing the problem of data collection, but by doing this the modeler will undoubtedly lose model precision and the ability to measure specific variables accurately.

The third and most recent study that used logit analysis to estimate the allocation of freight traffic among modes was the work performed by the Transportation System Center. They noted that if mode split models are to be used to calculate the demand for new modes, the models will need to explicitly include rates and service attributes which characterize a mode. From their empirical results, they concluded that significant improvement over past results may be achieved by attempting to group disaggregated commodities into more homogeneous groupings, by applying the methodologies developed to data at the disaggregate level, by refining the mathematical formulations used, and by gradually accumulating empirical knowledge concerning particular attributes determining mode split.

Probit Analysis

Probit analysis, like logit analysis, has been used extensively in the field of biometrics. This statistical technique, developed by Finney (*C-46*), can be used in freight modal split analysis to determine the relationship between the mathematical expectation of selecting a means of transportation and various modal characteristics and commodity attributes. Probit analysis provides a means of assigning a linear relationship to a probability function. Modal separation is accomplished through probability functions that can be represented by a cumulative normal-distribution frequency curve. This S-shaped curve is usually referred to as a sigmoidal response curve (see Fig. C-4).

Identification of the shipper's threshold response level is one of the key concepts of the probit analysis. It represents the indifference level where a shipper's preference is equalized in relation to selecting between alternative modes. The value X_1 in Figure C-4 depicts a shipper's threshold level, where any value greater than X_1 represents a shipper's preference of choice to mode K over an alternative mode. The threshold response levels are assumed to be normally distributed.

Type of model. A probit analysis type of model is a disaggregate, behavioral binary choice model for micro-level freight model split analysis. The focus of this type of model is on individual behavior rather than aggregated zonal modal choice behavior.

General formulation. The generalized formulation of a probit analysis is

$$P_k = F(\overline{V}_k) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\overline{V}_k} e^{-\frac{1}{2}\mu^2 d\mu} \qquad \text{(C-27)}$$

in which

$$V_k = \sum_{k=1}^{n} B_k X_k \qquad \text{(C-28)}$$

P_k = modal choice probability of mode k;
X_k = independent variables, such as shipment characteristics;
B_k = coefficients; and
$\overline{V}_k$ = shipper threshold value distributed as a normal independent random variable with mean = 0 and variance = 1.

Estimation of the coefficient, B_k, is made possible through use of the maximum likelihood estimation procedure. Further discussion on this type of approach can be found in Finney (*C-46*).

Application of Model. Hartwig and Linton (*C-18*) used probit analysis to model the individual shipper's mode choice between truck trailer load and rail carload shipments. Their analysis was limited to observations from a single shipper for a particular group of consumer durable household manufactured goods. As far as can be ascertained, this work is not only the most recent effort in this area, but also the only applied work on probit analysis for freight modal choice analysis at the disaggregate level.

Preliminary testing of the model was limited to four variable factors, expressed principally as differences. The variables used were: (1) the difference in truck and rail freight charges, (2) the difference in truck and rail transit times, (3) the difference in truck and rail reliability, and (4) the value of commodity. The formulation was designed to determine the probability of making a truck shipment.

Tests used to assess the statistical validity of the model

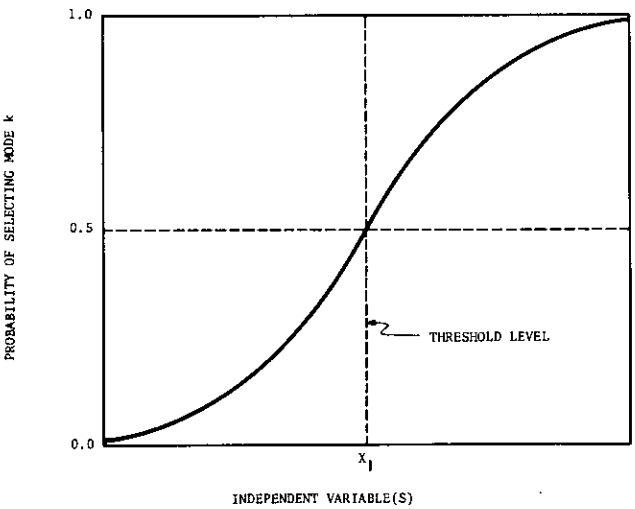

Figure C-4. Sigmoidal response curve.

were: (1) the t-test to determine the significance of the coefficients, (2) the likelihood ratio test to determine the significance of the probit function, and (3) the pseudo-R^2 measure for comparing the effectiveness of the model with other modeling techniques tested.

In an attempt to develop the best model formulation, three behavioral hypotheses were tested. In the first, only time and cost were included as independent variables of mode choice; in the second, the reliability measure was added; the third included not only all the previous external factors but also the shipper controlled measure, the value of commodity. Their initial belief was that the function with the most number of modal choice variables (the final formulation) would also be the most statistically explanatory and the most accurate estimator of mode choice. The model was based on a data base comprised of 619 shipment observations (134 truck and 485 rail shipments).

The probit model was able to predict the correct mode for shipment approximately 90 percent of the time when adopted to classifying individual observations by an arbitary cutoff value. Hartwig and Linton choose the value 0.5 on the sigmoidal response curve as the shipper's indifferent point.

Hartwig and Linton concluded that the probit analysis form is applicable to disaggregate freight mode choice modeling. Their analysis showed that binary mode choice (truck or rail) is more sensitive to changes in freight rates than either changes in transit time or reliability. In fact, time in the model used was statistically insignificant. They qualified this result as largely due to the severe limitations of the data base.

Data Requirements. Hartwig and Linton originally intended to obtain data from both carriers and shippers. Unfortunately, they were unsuccessful in their efforts to obtain carrier shipment data. However, they were able to obtain shipper data from a single firm in the form of 1,213 audit copies of freight waybills for both rail car loads and truck trailer loads for a particular commodity class (household consumer durable goods). From the bills they determined:

- The origin and destination of the shipment, from which they derived mileage.
- The date the shipment was shipped and received, from which they determined transit time.
- The mode of transportation (truck or rail).
- The freight rate and total freight cost charged.
- The type, weight, and number of pieces of the commodity shipped, from which they determined value per hundredweight of the commodity.

The micro-level data gathering effort was hampered due to two major problems: (1) lack of data availability in any form, and (2) the shipper's concern over the confidentiality of the data used.

Four variables were selected for use in their model. These were:

- Modal difference in transit time.
- Modal difference in freight cost.
- Modal difference in reliability.
- Value of commodity shipped.

Transit time was considered important because of the perceived capital cost incurred by the shipper when goods are tied up in transit. Multiple regression equations were developed to determine the values for missing transit times based principally on distance.

Freight costs were used in place of distance and weight-of-shipment variables, although these variables are implied within the freight cost variable. Cost of transportation is clearly an important factor in decisions of mode choice. Assuming the shipper behavior is rational and other factors are equal, he will always choose the least-cost means of transport.

Reliability of a mode or the variability in expected delivery time is important to a shipper if it affects his cost of maintaining safe stocks or adversely affects customer satisfaction. There is no simple, easy way of quantitatively measuring reliability. Hartwig and Linton used the standard deviation in transit times as a measure of reliability.

Value of commodity was the only internal (noncarrier controlled) variable explicitly included within their model. This variable, expressed as the retail value per unit of shipment, was determined from the shipper's price catalogue. This factor was considered important because it directly reflects capital costs incurred by the shipper while the goods are tied up in transit.

The nature and availability of the data preclude the inclusion of more variables in their analysis.

Evaluation of Method. The study by Hartwig and Linton clearly demonstrated that probit analysis can be applied to freight modal split analysis. However, their model would require expansion if it is to be applied as a micro-level policy tool. Shipper attributes and commodity attributes should be added to make the model more useful to analyze a wider range of commodities.

Researchers desiring to use disaggregate freight data must confront the problem of data availability. Carriers as well as shippers usually do not collect or record the type of data needed for micro-level analysis. If the data are available, the problem of confidentiality must be faced.

Probit analysis is ideally suited for relating observed shipper behavior to factors for determining mode choice between two means of transportation. Besides the problem of data availability, the probit analysis has several major drawbacks. First, probit analysis requires a more time-consuming calibration procedure than most other models. Second, commodity type is not considered. Third, the model is binary; that is, only two modes can be analyzed.

DATA REQUIREMENTS, SUMMARY AND CONCLUSIONS

Review of Modal Choice Models and Their Data Requirements

All freight mode split models have attempted to replicate the decision-making process of shippers in deciding among modes. Researchers have experimented with a wide range of mathematical forms in their desire to discover a rational, explainable basis for modal choice modeling. The methods described in this appendix have at best been tested only on a very limited basis. The inconclusiveness of results obtained is usually attributed to problems of data

availability. None of the methods have been tested enough to determine their feasibility or practicality. No consensus has developed over which method is best. No method has been applied to the solution of a specific, state-level freight issue or problem. In short, much work remains to be done simply to sort out and identify which models hold the greatest promise for further development as practical tools. Until then, freight mode split models have limited applicability in statewide transportation systems planning.

Thus, the present state of the art is only the initial stage of development. Underlying the lack of concensus are a number of major unresolved questions, including: (1) whether to use aggregate or disaggregate modeling techniques, (2) agreement on what constitutes the relevant variables to be included, (3) the "level" at which such modeling should take place (for the individual firm or for all firms within a geographic area), and (4) the degree of homogeneity required and whether different commodity groups must be modeled separately. These questions directly affect the characteristics of data required for modal choice modeling purposes; which for the most part is simply commodity or traffic flow data.

The main alternative centers around the form of the data; that is, whether it should be aggregate or disaggregate. The former is really a misnomer in that all data are disaggregate when originally collected. However, if obtained by governmental agencies, data must be aggregated prior to public release to provide confidentiality. Disaggregate commodity or traffic flow data do not exist, at least from public sources. If these types of data are required, they would have to be collected directly from shippers or consignees, an expensive, time-consuming process at best. Adequate data for disaggregate modeling may never become available due to (1) shipper's and carrier's reluctance to release such information, (2) the probable high unit cost of data acquisition, and (3) the tremendous variety of commodities and choice situations that would have to be reflected in a data collection program. Disaggregate-type freight data have yet to be successfully collected on other than a research basis. On the other hand, aggregate commodity or traffic flow data are available with some exceptions (mainly motor carriers) from a number of principal sources listed in Appendix B of *NCHRP Report 178* (*C-54*). However, aggregation of data often results in a significant loss in the variability of important parameters, which is one of the pitfalls disaggregate models can avoid.

In addition to the aggregate-disaggregate problem, many of the present commodity or traffic flow data contain insufficient detail on commodity and transport level-of-service attributes. Particularly crucial is the general lack of information on (1) rates or the amount paid by the shipper or consignee, (2) transport time, and (3) time reliability, which are common and important variables of today's modal choice models. (The options for obtaining such data are discussed in Appendix E.) Information on some of the other attributes listed in Table C-1 is equally difficult to obtain; however, these attributes tend to be used less often in models developed to date. Existing mathematical forms can only explicitly include a limited number of relevant (statistically significant) independent variables. The lack of agreement on significant attributes hinders development of suitable data collecting programs.

Given the present state of the art of freight modal split modeling, little near-term application of mode choice modeling techniques at the state level is anticipated. It is anticipated, however, that continuing research efforts will be made to refine and improve the mathematical form used, especially in determining the relevant variables affecting the freight modal choice decision. Testing of these models will continue to be limited to specific cases (a particular commodity movement within a specified geographical area) or to very generalized, macro-scale aggregate studies. It is not foreseen that the explanatory powers of these models will improve substantially until existing data limitations are substantially lessened. Hence, the key to improved models is better data.

Specifically, researchers of freight modal split should concentrate their efforts on:

- Development of homogeneous commodity groupings for aggregate data testing.
- Testing of disaggregate models at various levels of aggregation (commodity and geographical).
- In-depth analysis of the particular variables determining mode choice.

The critical element in any freight modal split analysis is elimination of heterogeneity within aggregate data sets. It is not practical to assume that mode split analysis at the statewide level can be performed at any level lower than the STCC 3-digit commodity level or some other similar coding system, such as TSC 3-digit commodity codes (*27*). For this reason, it is strongly suggested that any massive data gathering effort be preceded by a detailed study on establishing a minimum number (a couple of hundred would seem to be the maximum) of aggregate groupings of homogeneous commodities. These groupings should exhibit similarity in the following characteristics: (1) similar modal split distribution, (2) the same independent variables determine mode choice for each commodity, and (3) these determinants of mode choice have similar values. Two studies, one by the ICC (*47*) and one by TSC (*27*), have had a certain degree of success in addressing this problem of aggregating commodities into homogeneous groupings. However, there is a need for further experimentation and refinement of these commodity groupings.

The scarcity of data has hampered development of the model itself and is usually put forward as the rationale for excluding important variables from the freight modal split models that have been published to date. However, even when disaggregate data were assembled for use in their studies only a handful of variables were tested and fewer were deemed relevant. The independent variables most commonly used are:

- Weight of shipment.
- Distance shipped.
- Value per ton.
- Commodity type.
- Annual tonnage of the commodity shipped.
- Freight rate charged.

- Transit time.
- Measure of reliability.

Researchers of freight mode split from empirical results generally agree that mode choice is very dependent on the type of commodity shipped. If it is assumed that a shipper has a general knowledge of all alternative modes available to him and their characteristics, and that he acts in a rational manner in an attempt to maximize the amount of profit received or, conversely, to minimize the cost to the firm, selection of a means of transportation will be made on the basis of a least-cost criterion; that is, to maximize the firm's profit by minimizing transport charges, assuming all other factors are equal. Normally, however, such is not the case. Mode transport time, time reliability, and the value of the goods shipped can greatly affect a firm's warehousing costs (cost of inventory and the costs of maintaining safety stocks) and, therefore, affect the firm's policy on mode selection. Thus, the first task in any modal split analysis should be one of identifying which of the mode characteristics and commodity attributes are most significant to mode choice and somehow quantify the importance of each of these factors.

Further effort must be spent to determine methods of accurately predicting present and future freight rates, the effect of total distribution system costs on the shipper's willingness to pay for transport services, and the effect these costs have on the weight of shipment before the freight modal split model can function with some degree of success within the structure of statewide transportation systems planning.

Desired Capabilities and Program Levels

The need is foreseen for states to develop procedures for determining the allocation of freight between modes of transportation to assist in determining the effects of policy or system changes. Not only must these procedures predict freight modal split; they must also be in agreement with other elements of the transportation planning process (demand estimation, network analysis, and direct and indirect impact analysis). By application of a three-stage freight modal split modeling methodology approach, states would begin filling a void that now exists.

By use of the definitions estabilshed earlier in the report, three different program levels are described, as follows:

Stage I. Develop state capability to prepare total demand estimates by individual mode using historical trend extrapolation techniques and linear probability functions. This is discussed in Appendix B.

Stage II. Develop state capability to prepare interregional demand estimates by aggregate commodity groupings by individual mode using mathematically based freight modal split modeling techniques, such as the abstract-mode or commodity approach.

Stage III. Develop state capability to prepare intercounty, commodity flow estimates by individual mode using disaggregate behavioral mode choice models (logit, probit, and discriminant analysis functions).

The three-stage approach is built on the premise that a state should acquire a general knowledge and understanding of the existing freight transportation system before any serious attempt is made to allocate freight to individual modes due to changes in freight systems plans, changes in freight modal choice attributes, and changes in freight demand distribution estimates.

Data Required for Modal Choice Modeling

Models used to predict probabilities of mode choice selection require two main sources of data: (1) traffic flow data, and (2) information on variables deemed relevant to determining mode choice. Details on the data required for Stages I, II, and III are given in Table C-3.

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TABLE C-3

DATA REQUIRED FOR MODAL CHOICE MODELING

CATEGORY	INFORMATION OR DATA REQUIRED
	(a) Stage I
Traffic flow	1. Estimates of annual state and national modal traffic flow data in tons and ton-miles compiled from secondary sources, such as the *Census of Transportation* (*C-7*), the ICC/FRA one percent waybill sample (*C-43*), *Waterborne Commerce in the U.S.* (*C-47*).
Mode choice variables	1. Historical trends of national modal distributions by year, average haul (mileage) in mileage blocks, average shipment size.
	(b) Stage II
Traffic flow	1. Annual traffic flows between state regions (internal movements), by commodity grouping. 2. Annual traffic flows between state regions and other states and multi-state areas, by commodity grouping (external movements).
Mode choice variables	1. Average shipment size, by aggregate commodity groupings. 2. Distance between zonal pairs (straight-line and circuity factor). 3. Average value per ton, by commodity grouping. 4. Average freight rates charged, by mode between zonal pairs, by commodity grouping (see Appendix E). 5. Average transit time, by mode between zonal pairs (see Appendix E).
Commodity aggregation	1. Up to 20 groupings (e.g., bulk, nonbulk, special, or 2-digit STCC codes).
	(c) Stage III
Traffic flow	1. Disaggregate commodity traffic flows between county pairs for internal movements and between counties and other states or multi-state areas for external movements.
Mode choice variables	1. Weight of shipment, in tons. 2. Value per ton of commodity shipped. 3. Total transit time. 4. Time reliability. 5. Freight rate charged. 6. Distance shipped.
Commodity aggregation	1. Homogeneous commodity groupings (may require up to 200 classes).

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APPENDIX D

NETWORK ANALYSIS

INTRODUCTION

The purposes of this appendix are (1) to describe network analysis techniques having potential application in statewide freight transportation planning and (2) to identify the types of data required by these methods. The first part deals with multimodal networks; in the remainder, examples are drawn from rail planning because there has been more experience in freight network analysis for this mode than for other modes in the public sector. This appendix is the third in a series devoted to identifying freight data requirements for statewide transportation systems planning.

Description of Network Models

Network models are procedures that mathematically simulate or describe relationships and interactions between various physical components of a transportation system. They are capable of being manipulated by the alteration of a particular set of input and decision rules to gain insight into the consequences of planned changes in freight transportation systems.

Network models (also called traffic assignment models) are designed to assist transportation planners in developing, analyzing, and comparing link (network segment) and node (link end and modal interface points) traffic loadings of alternative transportation systems. These models are used principally to simulate current traffic volumes on schematic networks of transportation systems and to forecast probable future volumes. The major inputs to the models are trip interchange data developed from bill of lading or waybill surveys, or developed from demand estimation techniques. (Several demand modeling procedures are described in Appendix B.)

The basic process of traffic assignment is used to (1) prepare estimates of freight traffic likely to utilize the transportation network tested and (2) provide the inputs for the development of system revenue and cost estimates for the preparation of net operating income statements.

Different levels of analysis are possible. Statewide transportation planning deals principally with macro-scale planning (such as the analysis of interregional traffic flows), whereas operations studies (such as facility capacity studies) are concerned with specific system links or facilities. The latter type of study usually is done by freight carrier management to improve the efficiency of internal operations.

The major objective of network models is to identify, measure, and evaluate the consequences of proposed changes in facility use, routings, and corporate ownership.

Analogy to Passenger Network Models

Essentially, freight network models are similar to passenger models in structure and basic planning methodology. Both require schematic networks, routing procedures or algorithms, and either trip interchange tables or trip interchange models. The following three externalities have hindered the development of freight transportation network models:

- Large numbers of commodities involved (where commodity flows are being simulated).
- Lack of publicly available information.
- Complexity of the freight transportation system, including management or corporate policies that affect traffic flow patterns.

Passenger travel effectively pertains to the movement of a single commodity—people. Federal, state, regional, and local transportation planners over the past two decades have acquired extensive knowledge and understanding of the person movement sector, both in the transit and automobile modes. Reliable passenger travel information has enabled planners to calibrate, refine, and improve on their modeling approaches to person movements.

In freight transportation, however, this is not the case. Freight shipments are far more complex than person movements. This is due to the multiplicity of freight movements, which exhibit distinct distribution patterns; thus, goods movement can be (and has been) classified into literally thousands of discrete commodity groups. Furthermore, freight carriers are hesitant to release any detailed information on their operations. Thus, freight information availability at the micro-level is considerably less than person movement data. Finally, the freight transportation system is much more complex than the person travel system. The freight network involves (1) more modes of transportation, (2) more types of vehicles, (3) more complicated physical distribution facilities (e.g., terminals, yard facilities), and (4) more complicated routing decisions (for example, train make-up and reclassification rules) for freight between origin and destination.

In conclusion, it can be stated that development of tools and techniques for analysis of person movements has reached a much higher level of sophistication and application than those used for the study of freight movements.

Types of Network Models

Network models are classified, in this text, by the type of methodology employed in the determination of traffic routings within the traffic assignment function. Traffic routing procedures that can be mathematically derived by existing computerized assignment processes (e.g., Moore minimum path algorithm (*D-1*)) are classified as *mechanical* process models. Models that presently are not applicable to computerized assignment processes (e.g., circuitous routings due to corporate management policies) are categorized as *manual*.

Model Inputs

The four essential data requirements for any network analysis are:

1. Network configuration.
2. Network parameters.
3. Interzonal trip tables.
4. Routing criteria.

Network configuration. Network configuration is defined as an abstract description of all interconnections (nodes) and segments (links) of a transportation network which will sufficiently delineate and depict the real world or proposed transportation system under consideration.

A *node* may represent a freight terminal, an intermodal transfer point, an interline junction point, or it may cover a group of freight stations. Depending on how detailed the network is, one or more nodes could be used to represent a particular function (such as a railroad yard) and its surrounding service area.

Links are used to connect nodes, and usually represent transportation facility segments. Links may also represent artificial or synthetic connections (access links) or conditions between nodes (terminal penalty links).

The selection of segments should be based on definitive selection criteria. Usually factors such as traffic density, operating and physical characteristics, and connectivity between major trade areas enter into such delineations.

Network parameters. These measures refer to basic physical and operating values which represent a particular nodal or link characteristic. These values act as control parameters that shape the outputs of the model. For example, network values can include measures of distance, time, cost, and capacity.

In most computerized or mechanical traffic assignments processes, a single impedance value (measure of flow resistance) is necessary for determining interzonal routings or minimum path calculations. Computer assignments are usually based on minimizing travel time, distance, or some derivative function of these. No additional network parameters are necessary for assignment purposes. However, other measures, such as link capacities, nodal delays, and interchange penalties or prohibitors do allow for the development of more realistic routings and more meaningful results. Other descriptive data, such as weight of rail, type of waterway, age of pipe, are useful to develop detailed summaries of the network.

The minimum data required for computer assignment include nodal and link identification numbers and link impedance values.

Interzonal trip tables. These tables describe the total quantity (measure of flow, such as tonnages, vehicles, and/or revenue) shipped between two points or areas during a specified time period. These points or areas that define origins and destinations are called zones in network analysis. A *zone* can depict either a particular geographical region or a market area. Zone size can differ according to the purpose of the analysis; a micro-level analysis may require very small zones (such as census tracts), whereas large aggregations of areas (such as counties, states, or groups of states) may satisfy macro-level study requirements. Therefore, an interzonal trip table is no more than a collection of traffic flows between individual origins and destinations. Routings are not specified, only quantitative measures of interzonal flows. Trip tables usually are arranged into a square matrix, with each cell depicting the one-way directional flow between a distinct pair of zones.

Trip tables are either derived from actual shipment records or estimated from demand forecasting techniques. Tables can be built for any available quantitative flow measure. For freight analysis, tables usually include data on vehicle trips, tonnage, and revenue (expressed in dollars).

Routing criteria. The fourth and final basic data requirement for network models is a criterion for developing, delineating, and selecting interzonal routings. This is most critical to assignment processes; without a reliable, realistic routing selection procedure the results are meaningless. This inputted criterion provides the mechanism for directionally delineating interzonal routings that are actually happening or are likely to occur under alternative transportation system arrangements. The formulation can vary, depending on the type of process—mechanical or manual. In mechanical processes the internal routing selection process must be mathematically derived and is usually based on some sort of minimum path algorithm utilizing impedance values (such as time or distance measures), whereas manual processes can be far less structured to the point of being determined solely by judgment decisions.

Model Outputs

The major output of network models is traffic volume estimates on each network segment (link) and through each node. Traffic volume estimates can be expressed in any traffic characteristic that can be described by an origin, destination, and quantifiable trip interchange value.

POSSIBLE APPLICATIONS TO FREIGHT PLANNING

Freight network analysis models are applicable to aid in the analysis of a number of important direct and indirect transportation problems and issues that relate to goods movement. The following list of direct and indirect uses for network models is not meant to be exhaustive but, rather, indicative of the variety of uses that can meaningfully be examined through the employment of freight network models.

Direct Applications

- Quantitatively measuring, evaluating, and comparing the consequences of proposed operational, policy, and physical facility changes through identification of the differences in network traffic distribution patterns between the present system and alternative plans.
- Studying in detail the distribution patterns (routings), network capacity utilization (link loadings), modal interface points (terminals), intramodal interchange points (i.e.,

railroad yards), and their effects on the total transportation system.

- Providing necessary inputs and feedbacks to other transportation planning models, such as environmental impact analyses.
- Providing a means to organize, compile, inventory, and display in an orderly fashion a wide variety of transportation-related network data.

Indirect Applications

- Assessing the effects of network system restructuring, such as railroad consolidations, mergers, and track abandonments.
- Analyzing transportation policy decisions, such as increasing modal freight tariffs.
- Determining financial viability of a system or segment of the transportation network.
- Identifying areas where improvements in resource utilization can be made.
- Assessing the effects of technological changes on freight transportation.
- Examining where available state and federal funds can best be utilized in supplemental subsidy/capital improvement programs.

BASIC METHODOLOGY

Any quantitative network analysis technique will basically follow the procedure shown in Figure D-1 and described in the following. The essential steps in the process are:

1. Determine geographic detail.
2. Delineate zones.
3. Map the network.
4. Select transportation facility segments.
5. Establish physical facility parameters.
6. Collect network data.
7. Assemble interzonal flow data.
8. Prepare codes.
9. Code.

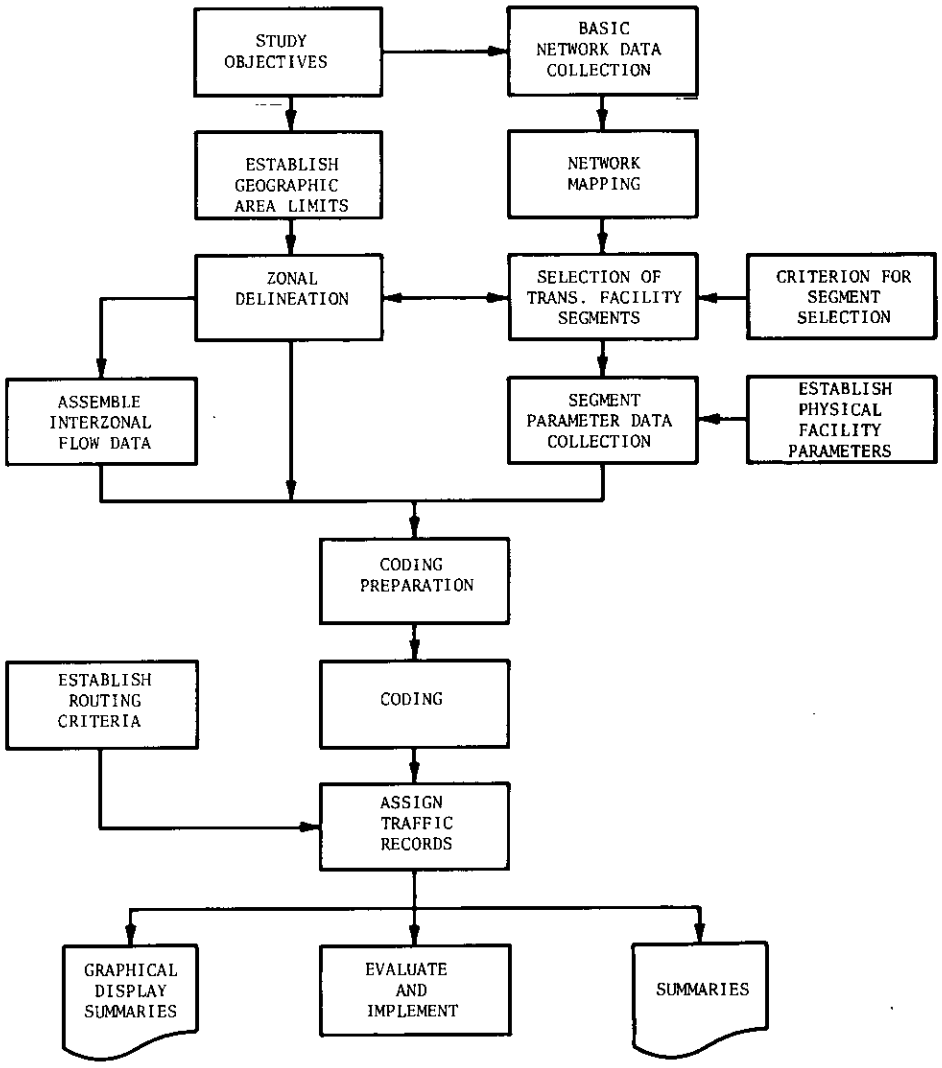

Figure D-1. Network analysis flow diagram.

10. Develop routing criteria.
11. Assign traffic.
12. Calculate, compile, summarize, and evaluate results.

Geographic Detail Determination

The initial step in statewide freight network analysis is establishment of the study's geographic area limits. Independent of the type of analysis, the geographic area limits must be comprehensive and inclusive enough to be able to identify all tributary market areas capable of generating freight flows to, from, or through the study area. A large percentage of freight movements within the state are through movements; that is, freight movements without an origin or destination located inside the boundaries of the state. Intercity freight carriers usually do not confine their operations or record keeping to coincide with state analysis requirements. Consequently, statewide studies of freight movements should not be circumscribed to include only those movements within a state. Establishment of geographic area limits must be made without regard to state boundaries, and in most instances these limits will be national (or at least multistate) in scope.

Zonal Delineation

For traffic aggregation purposes, the study area must be divided into zones. The basic rationale underlying zonal delineation is to identify tributary areas for accurately depicting traffic flows within the requirements of the analysis. Therefore, zone size may be varied. The "building block" for zonal delineation is the Standard Point Location Code (SPLC) (*D-2*), which identifies geographic areas by means of a six-digit code. For statewide studies, zones are ordinarily aggregations of states or counties within a state. The number of zones should be kept to a minimum, thus minimizing (1) the number of separate interchanges (interzonal traffic flows) and (2) the amount of preparatory or set-up work. Figure D-2 shows a sample of the type of hierarchical zonal system a state might use for network analysis. This zonal system was developed for Pennsylvania (*D-3*) to study mainline railroad freight traffic within the state under various system reorganization plans.

Network Mapping

Network maps are important for depicting the over-all transportation system characteristics. They also are necessary for efficient coding of the network.

Each freight system to be tested should initially be plotted over suitable-scale base maps, the appropriate scale of these base maps depending on the degree of network geographic coverage and the complexity. USGS topographic maps (scale 1:250,000 and 1:24,000) and highway planning survey maps (usually scale 1 in. = 1 mile) should suffice for statewide network analysis. Zones are drawn on overlays of these maps, together with the connecting links between the zones. After major nodal points are identified, a simplified network is selected based on link selection criteria and study objectives.

Transportation Facility Segment Selection

Uniform criteria should be established to assist the analyst in segment (link) selection. Usually, factors such as traffic density, physical and operating characteristics (e.g., link capacity measures, type of control system, speed limit), and connectivity between cities of a certain size or trade areas are included. It is important to realize that no set of criteria can replace judgment based in part on a knowledge of and "feel" for the freight system being depicted. The key to delineating a freight network is to develop an abstract system of links and nodes that accurately represents the system under study, including all potential major (high-density) routing options while keeping the number of links and nodes at a minimum. To illustrate, in the Pennsylvania study (*D-3*) links connecting major cities, railroad classification yards, and interrailroad interchange points were included. A relatively sparse system can still produce realistic traffic flows. For example, in the Pennsylvania study an abstract network of approximately 200 links depicted 15 railroad systems in the Northeast and Midwest, as shown in Figure D-3. The ultimate goal in network development is to delineate accurately each of the freight networks necessary to identification of traffic impacts.

Physical Facility Parameters

To efficiently and effectively assign traffic data to an abstract network, identification and physical facility parameters for each link and node must be established. Typically, the following information is collected for each node and link delineated in a network:

Node parameters:

- Identification code (discrete numbering system).
- Location name (e.g., nearest city and/or facility name, state).
- X, y coordinates (optional, principally for computer graphics).

Link parameters:

- Identification code (discrete numbering system).
- Delimiting node numbers.
- Length, miles (kilometres).
- Impedance value (e.g., average travel time, maximum allowable speed).
- Present traffic density measures (vehicles and/or tonnage per year) for calibration purposes.

Depending on the level of sophistication of the analysis, the following detailed information may also be required for network analysis:

Additional node parameters:

- Type of node:
  1. Switching—two or more links in a single system intersect.
  2. Interchange—two or more links from different systems intersect.

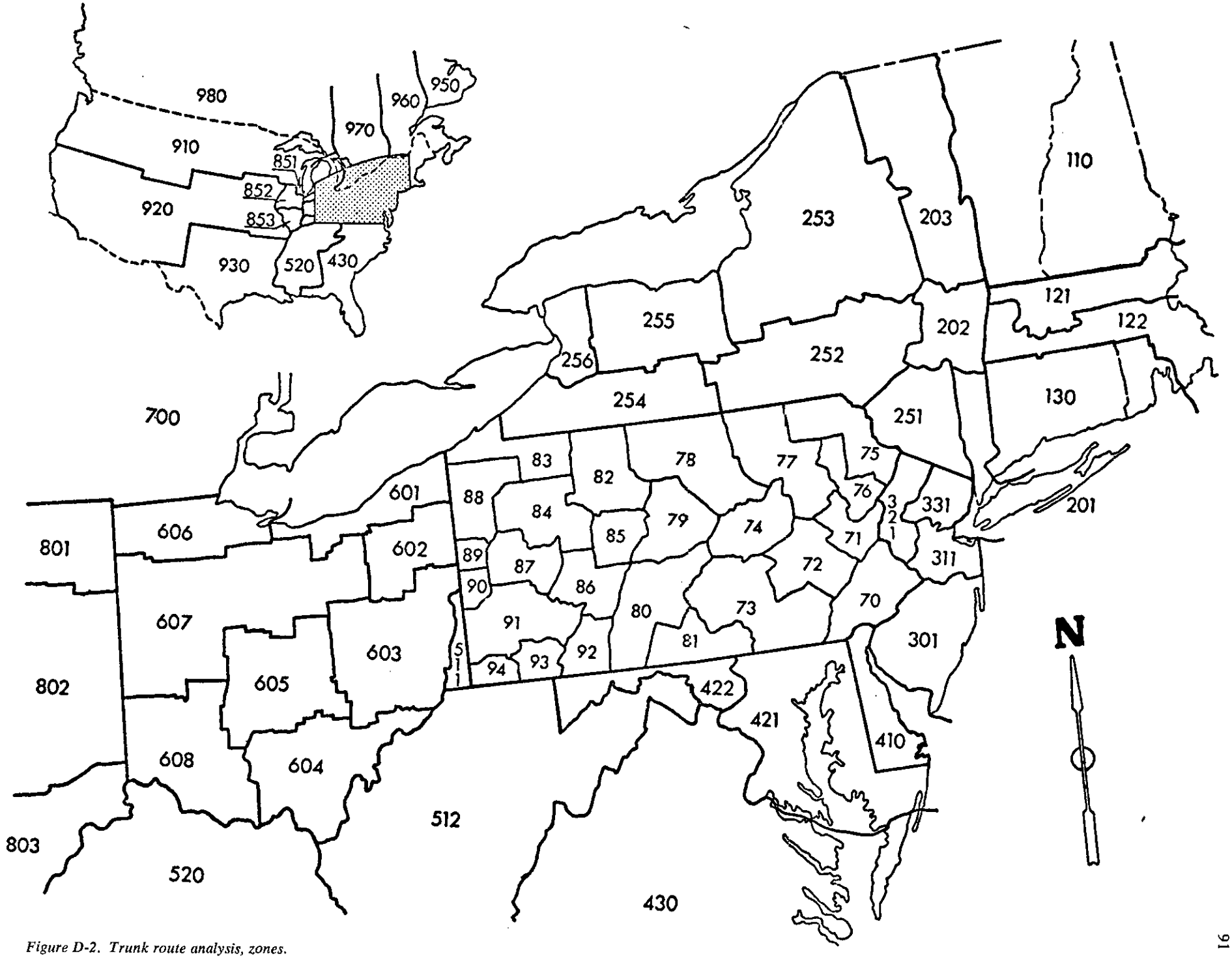

Figure D-2. Trunk route analysis, zones.

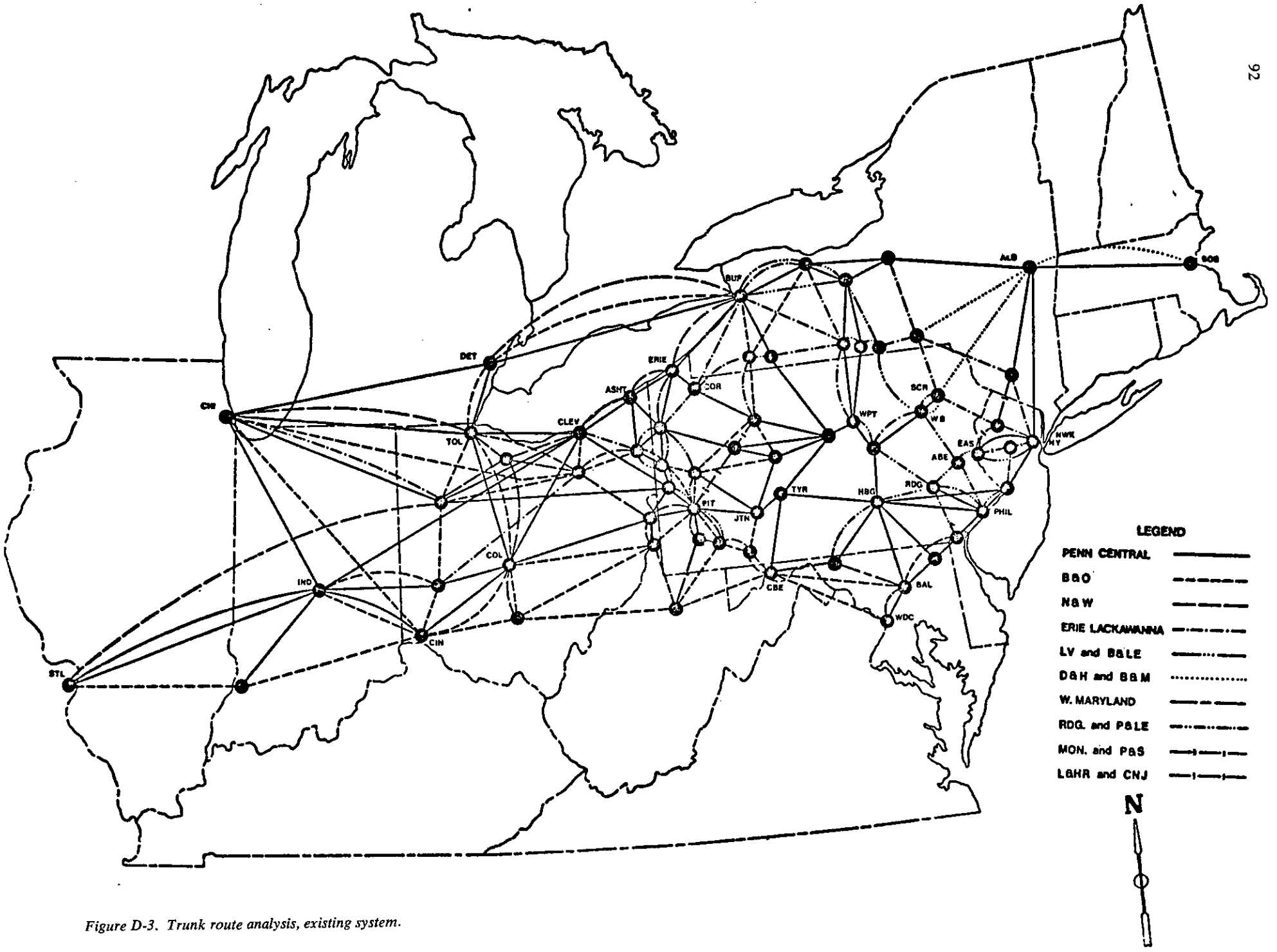

Figure D-3. Trunk route analysis, existing system.

3. Terminal—intermodal transfer point (e.g., freight terminal).
4. External—boundary point (e.g., state border).
5. Loading—freight station or other point where traffic can originate or terminate from the network.
6. Intermediate—location to distinguish significant physical or operating characteristic changes in a link (e.g., change in number of tracks in a rail line).

- Number of links (emanating from node).
- Ownership.
- Operating costs per vehicle handled or ton handled.
- Traffic density (vehicles/tonnage per year handled).

Additional link parameters:

- Modal identification (rail, pipeline, highway, air cargo, water).
- Type of link:

1. Mainline link—represents a portion of the actual transportation system (in special cases, railroad trackage rights may be depicted as distinct mainline links).
2. Access link—represents an artificial connection between mainline links and the zonal loading nodes.
3. Transfer link—a hypothetical link providing a means for registering an additional impedance or interchange restriction for computer manipulation.

- Capacity measures, usually expressed in vehicles and/or tonnage per unit time.
- Weight/commodity limitations.
- Vehicle/shipment horizontal/vertical clearance restrictions.
- Directionality of traffic (one- or two-way link).
- Ownership.
- Operating costs per vehicle-mile or per ton-mile.
- Detailed physical parameters (e.g., railroad—number of tracks, weight/age/type of rail, maximum gradient/curvature measures, number of highway grade crossings, turnouts, bridges, tunnels, etc.)
- Detailed operating parameters (e.g., railroad—type of control system, number of slow orders, functional classification).

Data Collection

The gathering of pertinent material for network modeling is often time consuming and expensive. Freight data are found in a wide variety of forms, consisting of maps, narrative descriptions, hard copy, and magnetic tapes. Some of these data elements must be reported periodically to federal and/or state agencies in their regulatory capacities. Other data are available only at the option of the carrier.

Although obtaining adequate traffic and revenue data is part of the data collection process, these data will be treated separately, because assembly of interzonal traffic values is so important to the over-all performance of any network assignment process.

Assembly of Interzonal Flow Data

Although interzonal flow data do exist, most of them are considered proprietary by freight carriers. There has been little systematic collection and recording of these data in a form desirable for statewide freight analysis. This lack of detailed information has discouraged public agencies from undertaking comprehensive freight analyses in the past. Until recently, the only publicly available information was the ICC 1 percent waybill sample of railroad shipments. Other origin/destination files (such as the Army Corps of Engineers' waterborne statistics, the Civil Aviation Board's air cargo file, and individual railroad's interline shipment files) do exist, but their usefulness to statewide freight planning cannot be realized without extensive modifications and retabulation. Information sought from these files includes interzonal movements of traffic (vehicles and tonnage) and revenue data on a yearly basis.

Network Assumptions and Coding

After the data collection phase is finished, network assumptions must be made for links where no adequate data exist. These assumptions often include: link travel time measures, link capacity values, link and node operating costs, and the amount of zonal traffic attributable to a loading node. Procedures must be established and fully documented to allow for these imperfections in the data.

Coding of a freight network must be based on an orderly and well-structured format and conventions that are designed to permit fast and efficient computer summaries and calculations. Although some network analyses may be done manually, this approach is less desirable because the procedures are often difficult to describe and replicate.

Network models require at least two and possibly four types of records to be coded. These are:

1. A "link" record describing the physical characteristics of different segments of the rail system.
2. A zone-to-zone "traffic" record.
3. A "node" record if computer graphics are desired as an output.
4. A "routing" record identifying the sets of links used for movements between zonal pairs (for manual assignments only).

The link record contains the one transport and cost parameter needed for computer manipulation. Identification information, such as delimiting nodes and link number, must be incorporated in the individual link records if mechanical assignments are to be performed. Link records can be added or deleted at any point to represent system changes. Similarly, if an ownership (corporate association) code is included on the record, the records can be changed to represent different system reorganization proposals.

The traffic record contains interzonal traffic volumes, such as total vehicles per unit time, total tonnage per unit time, and average revenue per vehicle. Traffic data will normally remain constant throughout the analyses unless different time periods are being analyzed.

The main purpose of the node record is to record geographic location information needed for computer graphics.

A secondary purpose is to input traffic use information for each node. Also, a node record may be used to provide a contingency check on the link record.

The routing record is only required where routings are determined subjectively, rather than by algorithm. This record is used to input interzonal routings and the market share (percent of total traffic) that will use a particular routing. Routings may be expressed as a sequential listing of links or nodes traversed in moving traffic between a zonal pair.

Development of Routing Criteria

This step defines the type of network model used. A mechanical process model will internally assign traffic to individual links through well-defined and highly structured criteria, such as a minimum-path algorithm (*D-1*). In manual processes, the interzonal routings are predetermined based on existing routing patterns or on "expert" judgments. Factors considered include comparative access to zonal originating traffic, physical and operational characteristics of system segments, competitive relationships, and the common railroad practice of maximizing the length of haul by the controlling (originating) carrier. Additional information on route choice theory and behavioral considerations underlying freight route choice by rail is discussed by Dralce (*D-4*).

The advantages of selecting mechanical process models over a manual process are that they (a) save time and manpower and (b) ensure that each route is selected in accordance with an established set of routing rules. The disadvantage is the lack of guarantee that the routings will reflect what is actually happening or that they will reflect what is likely to occur under alternative system proposals. Therefore, states may find that selection of interzonal routings for network analysis may best be done by analysts having suitable "carrier" experience instead of using computer-derived routings. Until internally derived routings can be improved to depict more realistic routings of freight, they should be used solely for very general or macro-level planning studies.

Assignment of Traffic

Interzonal traffic is "loaded" onto the network by assigning zone-to-zone traffic to the network links based on the routing criteria. Traffic is sequentially loaded on each of the links and nodes used in moving traffic from the originating node to the terminating node. One or more routings may be designated between two zones, depending on the type of route selection process used.

Calculation, Compilation, Summarization, and Evaluation of Results

Once all interzonal traffic records have been assigned to the study network, compilations of traffic (ton-miles and vehicle-miles), revenue, and costs for each link and node can be computed and summarized. A computer can be used to accomplish this accounting work.

In most traffic assignment processes, a calibration or checking phase is warranted. In this phase link volume estimates are compared with independently obtained traffic counts to see how closely the simulated system replicates the actual volumes. If major differences are noted, link characteristics and the routing criteria should be checked. The adjustment process can be cumbersome, tedious, and time-consuming if initial results are outside acceptable limits.

To test alternative plans, the same basic process as described is repeated. Link records are modified to reflect alternative system arrangements. Then evaluation of an alternative plan is obtained by determining the resulting differences in car-miles, ton-miles, costs, and revenues between the base case and the alternative being tested.

CONSIDERATIONS IN FREIGHT NETWORK ANALYSIS MODELING

From the development work done to date in freight network analysis modeling, the following general comments can be made: (1) data and modeling requirements must be defined early in the planning process, (2) a modeler must be able to determine the limitations and sensitivities of the model, (3) the validity of the input data must be determined, (4) verification of the model results is essential, (5) models can only simulate actual travel (existing analytical tools cannot perfectly incorporate every individual's decision-making process), (6) travel and routing decisions are not dependent solely on network characteristics, and (7) there are limitations to the types of mechanical assignment processes available to a modeler.

In addition to considering these general comments, the following items must be weighed:

- *Level of detail.* The degree of network aggregation will depend on the study's requirements. Similarly, traffic data detail also can dictate the network aggregation. For example, if the interzonal traffic flow data are summarized at the county level, there is no need to construct a network with a node at each transportation terminal (e.g., railroad station).
- *Data collection.* Due to shippers' and private freight carriers' reluctance to release disaggregate traffic information, there presently exists a general lack of publicly available freight traffic flow information for network analysis. Understandably, data must be aggregated prior to public release to protect information that is considered proprietary by the freight user or operator. This aggregation of data often results in a significant loss in the availability of significant freight movements, which has severely hindered the application of network models to freight transportation system planning.
- *State verification.* Another problem that is unique to state freight planning is that it is difficult to measure traffic passing through a state because almost all available traffic records do not include this information. Therefore, it is extremely troublesome, if not impossible, to develop state control totals for model verification.
- *Transportation system.* Major freight carriers usually serve multi-state regions. They do not recognize state borders when setting up their operating practices and routing patterns. Therefore, a freight plan that is "optimal" or

"best" for one state may not be for a neighboring state or may not be for the freight carrier.

EXISTING METHODS

Application of network analysis techniques to freight transportation issues is relatively recent, with most of the work having been done within a research rather than a planning context. There has been little actual application of these models. This stems partly from difficulties encountered in assembling required data and partly from the limited amount of freight systems planning done to date.

Chronology of Events

The first known application of network analysis to freight movements was in the late 1950's. Passenger-car equivalency measures for trucks were used in a number of highway capacity and traffic assignment techniques within the urban transportation planning process. This typified the level at which goods movement planning was conducted at that time.

In 1968 the Department of Transportation retained Peat, Marwick, Livingston & Co. to develop a freight network data base (*D-5*) for the Northeast that would be compatible with the input requirements of existing computer programs for assignment purposes. Geo-coded freight network maps, detailed link records, and link impedance measures were collected, compiled, and prepared for each of the region's major freight and/or communication networks (railroad, waterway, highway, electrical transmission lines, and natural gas and petroleum pipeline networks). Although the model was never fully implemented (no traffic assignments were made due to lack of adequate goods movement data), this study is a forerunner in comprehensive multi-modal transportation planning.

In the fall of 1969, the Office of Systems Analysis and Information of the Office of the Secretary of Transportation initiated a pilot study (*D-6*) to develop a network analysis methodology. It was planned that the methodology would provide rapid and flexible analytic capability for investigating and responding to a wide range of national multi-modal transportation policy and freight transportation decision alternatives. The principal strategy in model development was to adopt the Federal Highway Administration's traffic assignment process (*D-7*), used in urban highway planning studies, to the problem of national intercity freight transportation simulation. Abstract national networks for each of the major freight modes (highway, railroad, water, pipeline, and air cargo) were developed and linked to an analytic national zone system over which aggregate commodity interzonal traffic was assigned. Initial results showed enough promise to warrant continuation of the project (currently in the final documentation phase) to modify, refine, update, and improve the model.

With the financial failure of the Penn Central Transportation Company in 1970 and the increased interest of the Federal Government in saving railroad freight service in the Northeast and Midwest, the Federal Railroad Administration (FRA) in 1973 developed a computer network model (*D-8*) specifically for railroad planning. At present the FRA is experimenting with the mechanical routing process by impedance manipulation so that existing rail operations in the macro sense can be duplicated more accurately. Once again, the FHWA highway assignment program package was used as the basis for the rail model.

The United States Railway Association (USRA) used a large-scale network simulation model that was developed by Stanford Research Institute (SRI) in 1975 to help determine the sensitivity of various rail network planning scenarios under different conditions (*D-9*). Using a base network consisting of 147 super-nodes to represent the entire mainline rail network in the Northeast and Midwest, 30 options or variations of options were simulated. The network was expanded to 517 nodes for evaluation of the Final System Plan (FSP). The computerized model generates network and train statistics as routine outputs. These include train-miles and train-hours, gross ton-miles, and number of cars, tons, and trains by direction on each segment of the network. Train routing is done manually and inputted into the computerized process.

In 1975, the first known application of network analysis techniques to freight movements by a state was performed by the Pennsylvania Department of Transportation (*D-3*). A systematic process was developed for assigning interzonal traffic flows, expressed as carloads, tonnages, and revenues, to a "main line" regional rail network for the purpose of quantitatively estimating over-all costs, revenues, car-miles, and ton-miles. Computers were used to perform necessary bookkeeping and prepare summary outputs; traffic routings were done manually.

Other freight network modeling techniques have also been attempted, such as train performance models (*D-10, D-11*), linear programming (*D-12*), and micro-level physical distribution models (*D-13*), but none were applied, tested, or calibrated at the level necessary for statewide planning. Studies have been initiated at the Transportation Systems Center in Cambridge, Mass. to develop and implement a national freight transportation network simulation model. Currently, these modeling efforts are still in the development stage and adequate documentation is not available to the public.

Two models—FRA Network Model and Pennsylvania Department of Transportation Trunk Route Model—have been selected as examples of approaches that are available for statewide freight transportation system planning. The following analysis provides an evaluation of conceptual and mathematical modeling approaches with respect to policy sensitivity, data requirements, and other model performance characteristics. The basic distinction between these two modeling efforts, which can also be used to differentiate other network models, is the method used to determine interzonal routings.

The assessment of the FRA and PennDOT network models was performed using the following evaluation criteria:

- General formulation and characteristics.
- Policy sensitivity.
- Data requirements.
- Outputs.

- Application costs.
- Accuracy, reliability, and specificity.
- Freight transportation planning assessment.

FRA Network Model

General Formulation and Characteristics

The FRA network model (*D-8*) is a computer simulation model designed to assist railroad planners in developing and analyzing traffic loadings on a national railroad network. A secondary purpose of the model is to function as an information system data base. The model consists of an extensive railroad network (approximately 20,000 links and 16,000 nodes that includes slightly more than 200,000 route-miles and 332 different railroad carriers), several traffic interchange data bases, and a series of 45 computer programs to process the data. The model, which utilizes a modified version of the FHWA traffic assignment package, was developed by IBM in 1975. The seven basic steps in the FRA package are shown in Figure D-4 and listed here:

1. Code the network.
2. Build historical link records.
3. Build minimum impedance paths.
4. Build trip tables.
5. Assign traffic.
6. Apply capacity restraints.
7. Calculate, compile, and summarize.

The potential user of the model is provided with a detailed procedure manual including descriptions of methods and computer programs. The user is requested to develop subnetworks and completed railroad link data coding forms (in the form of punch cards) for each rail system configuration to be tested. A subnetwork must be based on a portion of the FRA national network, which is delineated in a two-volume set of maps available from NTIS (*D-14*). The FRA will then process the data through the series of computer programs. First, the computer package compiles the link data input file into a retrievable historical link record data base that can be manipulated, updated, and printed out at the user's request. The next step in this computerized process is the building of minimum impedance paths (trees) throughout the entire network. These paths are selected by an algorithm that determines the shortest distance/time path between any two nodes in the network. The next step in the process is development of a trip table and assignment of trips to the individual links in the network. The FRA has developed an origin-destination trip matrix that is an externally required data base for the model, but the user may provide his own trip tables or modifications to the FRA tables if desired; but this is not recommended. Presently, the FRA trip matrix contains such intermodal information as the number of cars, tonnage, and revenue associated with 1972 railroad goods movement. Values are assigned to the paths (series of links) by a modified version of the Moore route selection process (commonly referred to as the "all-or-nothing" method of traffic assignment). The model has the capability to load traffic on the network through a capacity restraint option that enables the program to update link impedance values in accordance with a predetermined built-in speed-to-volume function. The current model does not, however, utilize this option. The final step in the process is simply one of accounting, compiling, and summarizing the assignment results.

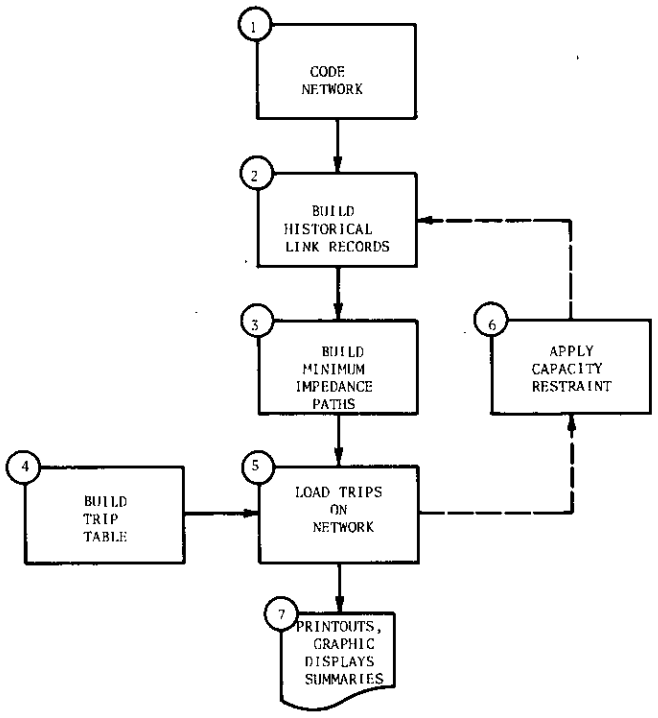

Figure D-4. Macro-diagram: FRA network model.

Policy Sensitivity

It is anticipated that the FRA model would be highly policy-sensitive for future federal and state railroad planning decisions. The model can assist in determining the over-all effects various railroad consolidations, mergers, and track abandonments would have on the direct (railroad carrier) and indirect (governmental agencies and the public) participants in the planned alternatives.

Data Requirements

The model requires rather extensive data before the assignment phase can be entered. Many of the data, however, have been collected, compiled, and coded by the FRA. The FRA requires from the user four major inputs, including:

- Railroad link data records, including zone number, state code, delimiting nodes, mileage, speed, number of tracks, signal system, density code, ownership, and trackage rights.
- Network impedance value (network parameter for determining minimum paths). Presently, distance is used, but time, cost, or any other quantitative measure derivable from the link record could be used.
- Interzonal trip tables showing station-to-station movements expressed in tons of cargo, freight cars, revenue, etc.
- Railroad system network maps with each system to be

tested completely delineated in strict accordance with FRA guidelines.

Outputs

The FRA package can provide numerous computer printout summaries. The following types of outputs are possible:

- Listing of historical link records.
- Error messages listing improperly coded link data cards.
- Node *x-y* coordinate listing.
- Listing of minimum impedance paths.
- Trip end summaries.
- Link traffic volume summaries.
- Selected link option, which summarizes all traffic movements assigned to a link.

The program battery includes also a series of programs that can produce plots on a CALCOMP drum or flatbed plotter. These programs are quite flexible, allowing the user to specify scale, physical plotter size, number of plates to be plotted, and the manner in which the information is plotted.

Application Costs

Currently, the model is available only through the FRA, which acts as a service agency with full control over the operation of the programs. The only requirement from the user is to provide the necessary inputs in the required FRA format. The application costs in terms of necessary funds, time, and manpower to the user are minimal, because much of the groundwork has already been completed by FRA. User's direct costs are generally low for network selection, but costs could be higher if the user desires to develop his own trip value matrix. Computer costs are variable, depending on network size, desired types of outputs, and number of assignments.

Accuracy, Reliability, Specificity

The difficulty with this approach is that the minimum-path algorithm produces routings that do not necessarily reflect real-world routings. Currently, the model cannot prevent unrealistic inter-railroad interchanges (such as would occur if a secondary line was shorter than a main line serving the same origin and destination). Also, multiple routings between stations are not possible in this type of "all-or-nothing" assignment.

Freight Transportation Planning Assessment

The FRA network model seems ideally suited for macroscale analysis of railroad traffic, from which over-all financial system assessments can be made. Because the process is computerized and operational, the potential user (e.g., state planning agencies) is free from the time-consuming task of manual manipulation of data that is so often required in calibration and validation of other types of analytical models. The model permits the user to test and analyze the effects caused by alterations in the physical plant of the railroad system, such as improved signal control systems, track rehabilitation, speed adjustments, and revised line capacity. Because of its extensive national coverage and its capability to produce graphic displays in the form of line plots, plans have been made to use the model as a repository for detailed network information data.

The current model has several major internal drawbacks, including:

- Inability to assign traffic to multiple routings.
- Inability to prevent unrealistic inter-railroad interchanges.
- Inability to take into account delays (e.g., reclassification) that would be encountered in yard operations.
- Inability of the internal routing algorithm to depict real-world rail routings, which are often quite circuitous due to corporate management policies.

External shortcomings include:

- The problem of updating yearly interzonal trip values.
- Revising link records parameters.

Despite these drawbacks, the FRA network model is still the most advanced, comprehensive, and operational network analysis technique available to the states for testing rail network alternatives.

PennDOT Trunk Route Model (*D-3*)

General Formulation and Characteristics

The PennDOT network model, referred to as TRAP, is designed to identify the over-all effect of proposed changes in facility use, routings, and corporate ownership. Effects identified are measured in terms of differences in traffic volumes distributed over the network. A flow diagram of this procedure is shown in Figure D-5. The model uses a specially prepared computer progam for bookkeeping purposes which is general enough to permit its application to other intercity freight modes.

Figure D-2 shows the geographic area and the zonal system used in the PennDOT study. A total of 71 zones in the northeast and midwest portions of the United States (25 in Pennsylvania) was used.

The network model was applied to evaluate the differences between the present railroad system (base case) and two alternative plans (USRA Preliminary Systems Plan and a plan proposed by the Commonwealth of Pennsylvania for reorganizing bankrupt railroads in the Northeast and Midwest). The base network, coded as 214 links and 67 nodes, included more than 16,000 route-miles on 15 different railroads (see Fig. D-3).

A flow diagram of this generalized procedure is displayed in Figure D-5.

The most difficult step is to directionally delineate interzonal routings and estimate market shares by competing routes. These judgments are based on such factors as competitive relationships, past "friendly" connections (or "anti-relationships"), comparative access to zonal originating traffic, physical and operational characteristics of the alternative trunk-line routes, and the common practice of maximizing the length of haul by the controlling (originating) carrier. Maps are used to enable the routing analyst

to visually and systematically select likely traffic distribution patterns between nodes and zones. A route is delineated by sequentially listing the links that are traversed when traffic is moved from one zone to another. This work is best done by experienced traffic routing analysts. Only in this way is there a reasonable guarantee that the selected routings will reflect the actual system traffic distribution patterns. Because the routings are manually determined, multiple routings between zones are used to represent alternative corporate routings. (A percentage of the traffic is then assigned to each route.) For example, in the PennDOT study there was an average of three interzonal routings per zonal pair, with a range from one to nine. The volume of traffic and the amount of interrailroad competition between zones are principal considerations in the routing selection process. It makes little sense to select alternative routings if there is a low volume between a zonal pair.

The trunk route analysis computer program itself consisted of several major phases. The first phase was to set up the several arrays in which carload, tonnage, revenue, and cost data could be aggregated on a link, node, and corporate system basis. In the second phase, traffic and routing records were read into the computer. Then the traffic and revenue data were assigned to available routings based on the market share estimates. Finally, the data were allocated to the affected links, nodes, and corporate systems. Once all traffic and routings records had been assigned, the third phase was to compute traffic (ton-miles and car-miles), revenue, and cost for each of the arrays and printout summaries.

Policy Sensitivity

The TRAP model was used by PennDOT to analyze alternative railroad reorganization proposals. Each plan was evaluated based on a set of service standards and state

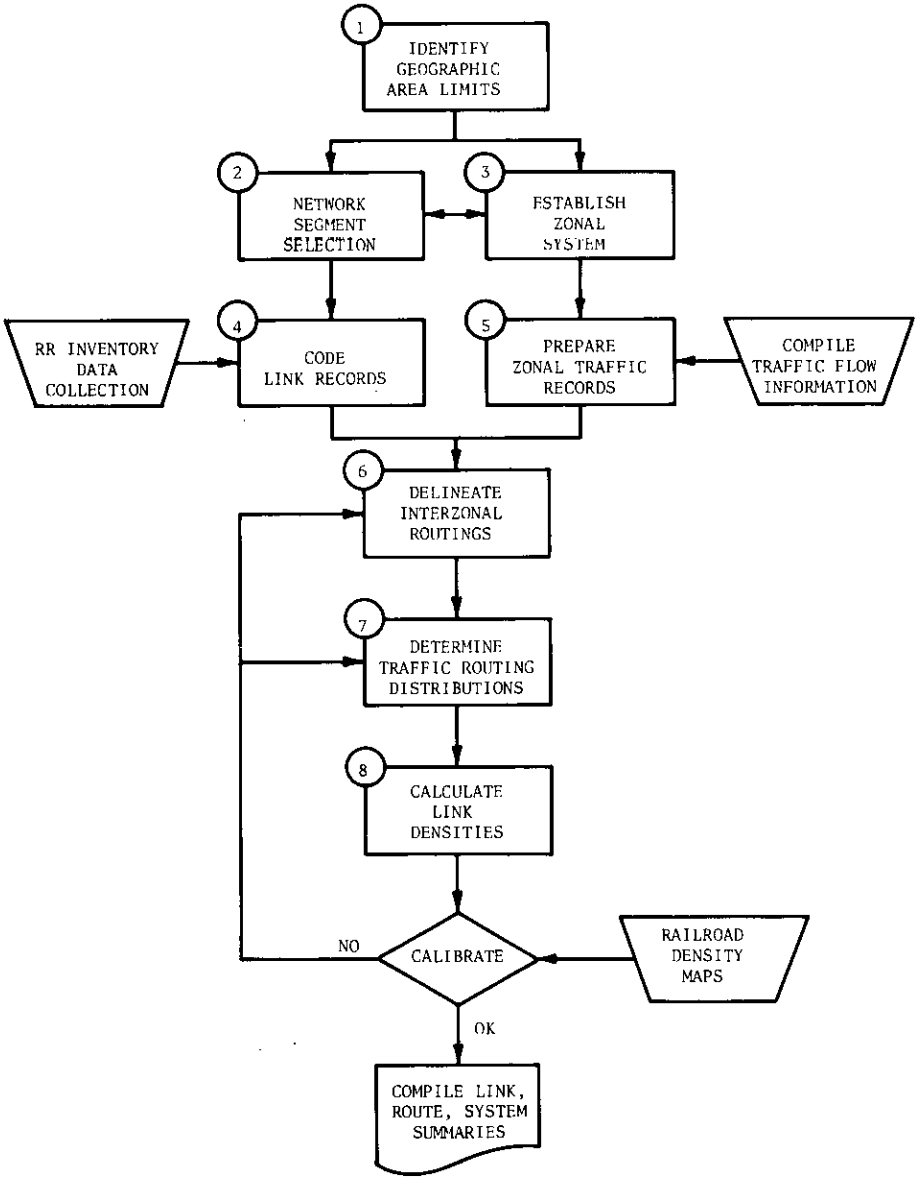

Figure D-5. PennDOT trunk route analysis program.

employment goals. The model is especially useful in determining (1) whether projected traffic estimates on major trunk routes can continue to contribute to railroad viability, (2) where railroad segments could be consolidated, and (3) whether a main-line railroad segment is a likely candidate for downgrading to secondary or branch-line status.

Data Requirements

There are four basic inputs to the PennDOT network model: (1) a "link" record describing the physical and operating cost characteristics of different segments of the rail system, (2) a zone-to-zone "traffic" record, (3) a "routing" record identifying the links used for movements between zone pairs, and (4) a railroad system cost record. Included in each is the following information:

- Link record—corporate system code, railroad index, link number, A- and B-node numbers and identification names, route and track miles, and directional link operating costs per ton and per carload.
- Traffic record—originating and terminating zone numbers, directional yearly traffic flows expressed in net tonnage and carloads, and the average revenue per carload in dollars by direction (A-B and B-A).
- Routing record—originating and terminating zone numbers, route number, percentage of total traffic attributed to route by direction, originating and terminating railroad codes, originating and terminating node numbers and city codes, sequential A-B listing of links.
- System cost record—numerical and alphabetical identification codes for each railroad, ton- and carload-related cost for each type of nodal traffic function (originated, terminated, received, and delivered).

Principal data sources used in the PennDOT study were: (1) the individual railroad companies' network, mileage, and density maps; (2) ICC/FRA 1972 waybill tape retabulation into Pennsylvania's zonal system; (3) USRA interline settling files for each of the seven Northeast and Midwest bankrupt railroads; (4) railroad annual report to the ICC; and (5) ICC *Rail Carload Cost Scales by Territories for the Year 1970.*

Outputs

The TRAP program routinely produces seven computer printout summary reports. These reports consist of three data reports (one for each of the input data files—link, traffic, routing), and four analysis reports (link, node, system, and railroad interchange reports). The program can also print out a file of route-link data that can be sorted and tabulated to produce a reference route-link report (this is commonly referred to as a select-link option in traffic assignments). Also, all input data are edited, with the stipulation that the analysis phase will not begin unless all data meet model specifications.

Application Costs

Computer costs are minimal with the majority of cost and time consumed by the delineation of routings.

Accuracy, Reliability, Specificity

For macro-scale estimates of freight traffic, the model's accuracy tends to be higher than existing mechanical processes. In the PennDOT study, agreement between railroad data and the simulated base case was extremely close, but the reliability of results is contingent on the accuracy of the inputted traffic flow data and on how well estimates of market penetrations or proportional split of a zone's traffic among competing routings are made.

Freight Transportation Planning Assessment

The Pennsylvania network model will help fill the existing void for rapid, macro-scale-level tools for policy and system-level planning. Although it was developed for statewide and regional rail planning purposes, the procedure and its supporting computer program are general enough to permit application to other intercity freight modes.

In short, the procedure that was developed is a simple, straightforward, and pragmatic adaptation of computer-based accounting to support manual estimates of the distribution of freight traffic. The procedure does not rely on theory or algorithms for routing decision-making. The major drawback of this type of process is that it can be influenced by subjective biases, although calibration and checking phases are included to help uncover major distortions. The computer program is relatively quick and inexpensive to operate. The interaction process between the analyst and the computer can, and should be, further refined to reduce the manual effort involved in changing data entries.

STATE ACTIONS AND DATA REQUIREMENTS FOR NETWORK ANALYSIS

A need exists for states to develop analytical procedures that are capable of identifying the effects policy or system changes will have on traffic routing patterns and on the individual components of the freight network. To the maximum extent possible, these procedures should be linked to other elements of the planning process (demand estimation, modal split, and impact analyses).

Using the three-stage program defined in Appendix A, the following approach is recommended:

- *Stage I.* Develop state capability to inventory freight modal networks and existing traffic flows by the collection and preparation of networks maps by individual mode.
- *Stage II.* Develop state capability to prepare macro-level estimates of interregional traffic flows by individual mode. Modeling techniques such as the mechanical process developed by the FRA or the manual process used by PennDOT should be examined.
- *Stage III.* Develop state capability to prepare individual link and node traffic estimates at a finer geographic detail than Stage II (e.g., intercounty) by commodity type.

This staged approach is based on the assumption that a state must first acquire a general understanding and knowledge of the existing freight transportation system.

Network analysis models require four sources of information: (1) network configuration, (2) network physical and operating characteristics, (3) traffic flow data, and (4) routing information. Details on the types of data required for network analysis are given in Table D-1 and delineated by planning stage in Table D-2.

TABLE D-1

DATA REQUIRED FOR NETWORK ANALYSIS

MAJOR DATA CATEGORY	DATA ITEM
Network configuration	1. Boundaries of study area. 2. Zonal delineation.
Network parameters: Link parameters	1. Modal identification (rail, pipeline, highway, air cargo, water). 2. Delimiting node numbers (with location and type). 3. Link identification code (link number, and segment/route code). 4. Physical characteristics: Length (miles). Link type (mainline link, access link, "transfer" link). Capacity measures where appropriate (i.e., vehicles or tonnage per unit time). Weight/commodity limitations. Vehicle/shipment horizontal/vertical clearance restrictions. Detailed inventory parameters (i.e., railroad—number of tracks, weight/age/type of rail, maximum gradient/curvature measures, number of highway grade crossings, turnouts, bridges, tunnels, etc.) 5. Operational characteristics: Directionality of traffic (one- or two-way link). Ownership. Travel time measures (i.e., maximum allowable speed, scheduled time, average travel time). Control system utilized where appropriate. Operating costs per vehicle-mile or per ton-mile. Functional classification. 6. Existing traffic characteristics: Traffic density (vehicles/tonnage per year).
Node parameters	1. Node identification number. 2. Node coordinates (x/y coordinates). 3. Ownership. 4. Location (name, state, zone). 5. Number of links (emanating from node). 6. Type of node (switching, interchange, terminal, external, loading, intermediate). 7. Operating costs per vehicle handled or ton handled. 8. Existing traffic characteristics (in special cases): Traffic density (vehicles/tonnage per year handled) by traffic category (originating, terminating, or through).
Interzonal trip tables	1. Originating zone number (A). 2. Terminating zone number (B). 3. Actual or estimated traffic flows (AB/BA): Vehicles per year. Net/gross tonnage per year. Total revenue/average revenue per vehicle or per ton. (In special cases traffic flows can be categorized by commodity type)
Routing data	1. Originating zone loading node number(s), ON. 2. Terminating zone loading node number(s), TN. 3. Percent of total interzonal traffic (if alternate or multiple routings are allowed). 4. Route number (optional). 5a. Sequential listing of links (to directionally delineate each interzonal routing), for manually prepared routings. 5b. Mathematical routing algorithm (i.e., minimum path algorithm), for mechanically determined routings.

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TABLE D-2

DATA REQUIRED FOR NETWORK ANALYSIS

CATEGORY	INFORMATION OR DATA REQUIRED
	(a) Stage I
Network configuration	1. Schematic network maps, by mode, compiled from secondary sources.
Network parameters	1. Identification of major intercity network segments, by mode. 2. Classification of nodes (loading, intramodal interchange point, or intermodal connection point). 3. Link distances.
Traffic flow	1. Estimates of annual traffic flows (net tonnage), by link.
	(b) Stage II
Network configuration	1. Detailed network maps, by mode, complied from secondary sources.
Network parameters	1. Link distances. 2. Average link travel times. 3. Link delimiting nodes.
Traffic flow	1. Interzonal trip tables of annual traffic flows (i.e., tonnage, vehicles, and revenues), by mode.
Routing	1. Network interzonal routing patterns derived from mechanical minimum path techniques or manually assigned by judgment.
	(c) Stage III*
Network configuration	1. Comprehensive, geocoded freight transportation network capable of being reproduced by computer graphic techniques.
Network parameters	1. Link parameters: length, travel time, maximum allowable speed, mode identification, capacity and commodity limitations, unit operating cost measures, delimiting nodes control system (if applicable). 2. Node parameters: type, time and cost penalties, modal interchange restrictions.
Traffic flow	1. Interzonal (county level) trip tables of annual traffic flows (net tonnage and revenue) by up to 200 homogeneous commodity groupings.
Routing	1. Actual routings between interzonal pairs. Information should include total transit time, path utilized, freight rate charges, commodity or shipment size limitations.
Mode split variables	1. See Appendix C for details.

* *Stage III*—Network analysis and mode split should be done simultaneously as a single element in the freight planning process.

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APPENDIX E

ECONOMIC EVALUATION

In this appendix, data required to utilize techniques for economically evaluating changes in freight transportation infrastructure or services are specified as part of the continuing identification of data needed for statewide freight transportation planning. This appendix is the fourth in a series devoted to identifying data requirements.

Unlike many of the activities discussed in other appendixes, methods for conducting economic evaluations are generally well known (for example, see Winfrey (*E-1*)). They are, however, highly dependent on certain types of data, especially information on costs and revenues and to a lesser extent certain transport level-of-service and commodity attributes. The principal challenge to the state transportation planner lies in assembling proper cost and revenue information. Unfortunately, this information must be derived or converted into the desired form; it does not exist as data that can be tapped directly. The purpose of this appendix is to focus directly on the data sources and conversion processes necessary to derive information needed for economic evaluation purposes.

The four principal kinds of information needed are (a) cost data, including both capital and operating costs; (b) revenue data; (c) transport time; and (d) time reliability. This examination of supporting data needs is restricted to these four items because they are more important than all others in carrying out economic evaluations.

BASIC CONSIDERATIONS

Kinds of Cost Data

Two kinds of cost data are required for freight systems planning: capital, or investment cost, which relates to providing the way and the transport vehicle, and operating cost, which relates to the cost of moving vehicles and providing services. This distinction is not always absolute; costs classified as operating generally make provision for recovery of capital and for return on investment. For example, in railroad accounting, certain costs of maintaining track structure, conventionally charged as an operating expense, would be capitalized under normal industrial accounting procedures.

Capital cost data, especially with respect to rail line rehabilitation, relocation, or upgrading, is becoming increasingly important as states take on responsibility for branch line preservation, removal of yards and terminals from urban areas, and development of intermodal facilities. Cost data may also be needed in relation to port development; however, the capital cost of the waterway itself (exclusive of ports) is a federal responsibility, although some minor participation in construction costs may be required of local jurisdictions.

Operating costs conceptually are more complex than capital costs because not only must unit cost data be obtained, but also the appropriate units of work (output) must be specified. Transportation planners should become thoroughly familiar with the different data sets, to know their strengths and weaknesses, and become capable of modifying cost data for use in specific applications. States should maintain sufficient unit cost data to meet a majority of their anticipated needs.

Cost estimating at the state level is often done by analysts responsible for many other phases of the work, not by specialists having long experience with cost data. The data used must be complete, yet at the same time reasonably simple and understandable to the lay person. Thus, for freight systems planning it is necessary to seek cost data that lie between the very generalized and the very detailed.

Aggregation and Level of Detail

In a great many planning applications, a fine level of cost detail is unnecessary; aggregated data may be entirely sufficient. An illustration of this point might be a multistate network simulation model where system or regional average costs might be sufficient for developing a state plan for physical facilities. However, this would not be the case if the problem confronting the state were choosing among railroad branch lines for subsidy purposes. In the latter case, the need for specific data having minimum uncertainty makes the use of aggregate data unsatisfactory. In general, standard unit cost data, adjusted to match the characteristics of the situation and to reflect regional differences, should be satisfactory for the large majority of the cost data needs for statewide systems planning.

In considering whether aggregate or disaggregate unit cost data are required, the following principles must be considered. First, it is always possible to aggregate from very detailed cost data, but never the reverse. Second, the greater the amount of detail, the more costly will be the acquisition of unit cost data. Thus, the planner is faced with a trade-off between the substantial time, effort, and cost involved in locating and developing unit cost figures and the added precision and assurance resulting from using more reliable data. Third, higher levels of detail do not necessarily ensure avoidance of potential controversy over the validity of the unit cost values selected for use. Systematic bias (generally noninclusiveness of all costs) is still just as much a possibility. Fourth, use of higher levels of detail concomitantly require more detailed estimates of quantities and condition, which further adds time and cost.

It is often useful to have on hand for rough estimating purposes some data on the approximate cost of replacement vehicles (locomotive, tractor, or tug and car, trailer, or barge) and on heavy maintenance of way and terminals. States might find it worthwhile to develop and periodically revise listings of such costs so as to have at least some data available for planning purposes.

Examples of Cost Compilation

Several examples illustrating the compilation of unit cost data suitable to systems planning are presented in the following. One involves capital and infrastructure costs for railroads; the others, operating costs for rail, motor carrier, air transport, and inland waterway transport.

USRA Procedure for Costing Rehabilitation of Railroad Lines and Facilities

This section presents the detailed and comprehensive rail rehabilitation costing procedure developed in 1974 for USRA by Bechtel (*E-2*). This costing example represents about the maximum level of detail that should be attempted in a systems planning application.

The procedure used a "needs study" approach. Samples of components of the system (track, signals, yards, etc.) were carefully measured as to their condition; the costs to bring the components up to a defined standard were estimated; and the costs were then expanded to represent the cost of rehabilitating the entire system. The procedure is applicable to new facilities as well as to rehabilitation.

USRA's objective was to obtain fixed plant rehabilitation cost estimates for the bankrupt railroads in the Northeast/Midwest region. The estimate was organized by major work components comprised of (1) running line systems (line-haul facilities), (2) yard systems (further subdivided into yards, service facilities, and minor shops), (3) terminals, and (4) major shops (major overhaul or rebuilding function for locomotives and cars). All of the railroad's physical components were assigned to the foregoing groupings. These components consisted of track, signals, yards, bridges, tunnels, servicing facilities, shops, buildings, freight terminals, marine terminals, electrical traction, other electrical facilities, and communication facilities. A series of work functions were devised for each work component or subcomponent. Figure E-1 shows the work functions developed for trackwork, along with the associated units of measure. Several hundred discrete functions were developed to cover all facility components.

For each work function listed, a unit cost estimate comprised of labor, equipment, and commodities (materials) was developed. As each estimate was prepared, underlying assumptions were made using different productivity rates. The final estimate was then made using the buildup of labor, equipment, and commodity costs from the classification or description of the item, the number required, unit and total hours, and hourly rate or unit price. Supporting the detailing of work functions were listings of (1) employee hourly wage rates used for different skill classifications, (2) equipment and associated hourly rates and (3) materials or commodities and their associated unit prices. All of these cost data were adjusted to reflect a particular time period—in this case, the third quarter of 1974. The derived work function costs were then used with independently derived work requirements to estimate the cost of rehabilitating the different components of the rail system.

Equally important to the unit costs developed for each work function are the assumptions and criteria underlying them; before undertaking costing activities, states must know exactly what the unit costs include (or do not include). This necessity for careful attention to details is illustrated in the following paragraphs, using the USRA costing procedure as an example.

Labor Crew and Costs.—All rehabilitation cost estimates assumed the use of experienced railroad labor. Downward adjustments might be necessary were outside contractors to be utilized, or new crews hired. Standard productivity was assumed in all operations even though productivity varies with weather, season, geographic region, traffic, work rules or methods, skills, working hours, and distance from the base of operations. Some allowance for lost time due to traffic, weather, travel, and breakdowns was included in the productivity rates. Wage rates were those in effect during the third quarter of 1974. The rates do not include any provision for premium time, nor do they include fringe benefits, overtime, taxes, and insurance. The latter were included in the estimate as an additive to labor cost.

Equipment.—All rehabilitation equipment was assumed to be the latest models having high productivity and in good

Code	Description	Unit
TR 21	Replace Rail With New CWR	Track Mile
TR 22	Replace Rail with New Bolted Rail	Track Mile
TR 23	Replace Rail with Fit CWR	Track Mile
TR 24	Replace Rail with Fit Bolted Rail	Track Mile
TR 25	Reposition Rail to Correct Gage	Track Mile
TR 26	Transposing Rail	Track Mile
TR 27	Grind Rail Surface	Track Mile
TR 28	Cross Grind Rail At Joint	Joint
TR 29	Weld/Grind Rail End Batter	Joint
TR 30	Bolt Renewal/Tightening	Joint
TR 31	Joint Bars and Bolt Renewal	Joint
TR 32	Field Butt Welds	Weld
TR 33	Raise 4" Out of Face	Track Mile
TR 34	Surfacing Out of Face (1" to 2" Raise)	Track Mile
TR 35	Spot Surfacing	Track Mile
TR 36	Line and Surface in Interlockings per Track	Turnout
TR 37	Sled Ballast	Track Mile
TR 38	Clean Shoulder Ballast (One Side)	Track Mile
TR 39	Clean Shoulder Ballast (Both Sides)	Track Mile
TR 40	Clean Crib and Shoulder Ballast	Track Mile
TR 41	Cross Tie Renewal	Tie
TR 42	Switch timber renewal	Timber
TR 43	Renew frog	Frog
TR 44	Renew switch points and stock rail	Set
TR 45	Renew crossing (diamond-4 corners)	Crossing
TR 46	Renew turnout complete (steel only)	Turnout
TR 47	Install panelled turnout	Turnout
TR 48	Weld/grind frog or switch	Each
TR 49	Weld/grind crossing (diamond - 4 corners)	Each
TR 50	Vegetation control (spraying brush)	Miles one side
TR 51	Brush cutting on track	Miles one side
TR 52	Brush cutting off track	Miles one side
TR 53	Drainage off track	Miles one side
TR 54	Drainage on track (ditcher-spreader)	Miles one side
TR 55	Renew grade crossings	Single track foot
TR 56	Haul and distribute ballast (surface)	Track Mile
TR 57	Haul and distribute ballast (raise)	Track Mile
TR 58	Haul and distribute CWR	Track Mile
TR 59	Haul and distribute bolted rail	Track Mile
TR 60	Haul and distribute CWR OTM	Track Mile
TR 61	Haul and distribute bolted rail OTM	Track Mile
TR 62	Haul and distribute ties	Tie
TR 63	Clean up and haul out CWR	Track Mile
TR 64	Clean up and haul out bolted rail	Track Mile
TR 65	Clean up and haul out OTM	Track Mile
TR 66	Clean up and haul out ties	Tie
TR 67	Renew spiking	Spike
TR 68	Renew plates	Plate
TR 69	Regage turnout	Turnout
TR 70	Haul and distribute panelled turnouts	Turnout
TR 71	Clean up and haul out turnouts	Turnout

Figure E-1. Track work functions. (*Source: Ref.* E-2)

condition. Equipment costs did not include overhaul, taxes, insurance, freight, fuel, and all other costs. Equipment additives were applied concurrent with the labor additive.

Commodities.—Third quarter 1974 prices from normal railroad vendors were used in the estimates. No escalation or discount was assumed on account of the magnitude of potential orders or change in supply/demand relationships. Material costs include delivery to the railroad. A "Buy America" criterion was assumed for all materials except rail and ties. Fit materials and commodities suitable for reuse elsewhere were costed proportionately to the comparable price of new items. Purchasing and storehouse costs were included as an additive to commodity cost. Supplies, which encompass nonpermanent materials such as power, lubricants, repair parts, cable, nails, wire, small tools, and other expendable items were applied concurrent with the labor additive.

If the analyst knew exactly how the foregoing unit cost components were accounted for in his estimate, his over-all cost estimate should be relatively sound. However, given the fluid nature of this particular cost estimate, a contingency factor often must be applied to account for unknown work which may become apparent later on and because of changes in productivity or facility changes introduced at a later point. In the USRA study no allowance was made for the escalation of labor and material costs, primarily because there was no requirement for scheduling the rehabilitation work to be performed. Many estimates do, however, include allowances for escalation, especially when the project is staged over time.

As can be seen, Bechtel followed a highly organized, systematic procedure in developing unit cost data for plant rehabilitation purposes. In spite of the vast array of work functions, commodities, and unit prices, the approach has nevertheless been criticized by a few who feel the resulting costs are too high (that is, the rehabilitation standards are either too high or estimates are systematically biased). This highlights the desirability of reaching agreement with interested parties beforehand on the approach and unit costs to be used in estimating capital needs. States should be alert to the possibility of distortion if cost data are developed solely by carrier management, by regulatory agencies, by state DOT's or by outsiders.

ICC "Rail Form A" Cost Calculations

As an example of a method of estimating operating costs, the ICC formula approach to determining unit cost is illustrated using Rail Form A, which is the method employed by the ICC to estimate variable and fully allocated costs of railroads. (This costing formula is not to be confused with Railroad Annual Report Form A, which through 1972 was the designation of the basic form on which the railroads annually reported financial and operating data to ICC.) Costs of common motor carriers of freight are estimated on an industry/regional basis by an analogous formula, Highway Form A, and for individual carriers by use of Highway Form B. Only Rail Form A is discussed here.

Rail Form A is a method of converting expenses in each account, as reported to ICC by the railroads, to unit cost, in terms of such output units (service units) as car-miles and gross ton-miles. Application of the formula identifies variable unit costs; that is, those costs which have been found to vary with changes in traffic levels. Variable costs include freight operating expenses, rents, and taxes (excluding Federal income taxes), plus an allowance for the cost of capital at the selected rate of interest on debt. In addition, the formula produces fully allocated costs—the sum of the variable unit costs, including cost of capital, plus constant costs (those costs that do not vary with the volume changes). The constant costs are prorated over all revenue freight on the basis of tons (terminal costs) and ton-miles (line-haul costs) without regard to kind or class of traffic.

The formula, which has evolved through the years, requires thousands of calculations even to execute it for a single railroad. However, the ICC annually makes the calculations by computer and publishes average unit costs by region of the United States (*E-3*).

The starting point for application of Rail Form A, which yields the unit costs discussed previously, is the accounting data reported annually by the railroads. Each reported account has been analyzed through the years by the ICC to determine its behavior (variability) with respect to work performed, measured in what the ICC calls service units. The ICC approach is to look for output units, or service units, that cause changes in the expense level of each account. It has identified about 30 such cost causal factors—number of loaded cars, car-miles, car-days, locomotive unit miles, etc.—each of which is used to explain changes in one or more expense accounts. Some of these service units were identified by direct analysis; for example, the cost of preparing waybills is a function of the number of waybills prepared. Others were identified through regression analysis. In the latter case, it is usually found that costs in a given account are partly variable with volume and partly unrelated to changes in volume. For example, the cost of maintaining running tracks was found to be 57 percent variable with changes in gross ton-miles (weight of locomotive, cars and contents, and caboose times miles). Thus, an increase of 10 percent in gross ton-miles is found to cause a 5.7 percent increase in maintenance of running track.

After the aggregate dollars reported in each account are separated into variable and constant portions, the variable portion is divided by the relevant service unit to obtain variable unit cost. This produces the finest level of unit cost detail. It is possible, although cumbersome, to estimate costs for a particular movement by developing appropriate service units and multiplying each by its unit cost. For less precise cost determination, the ICC has grouped all accounts into four main service units—carloads, car-miles, hundredweight, and hundredweight-miles—and has developed variable unit costs for each.

An example of the type of information presented is shown in Figure E-2, which presents sample pages from Table 3 of *Rail Carload Cost Scales, 1973* (*E-3*). From this table one can compute the variable and constant expenses for a given movement, having first determined the weight of the shipment and the mileage.

Tables in *Rail Carload Cost Scales* contain costs for seven ICC regions of the United States, as well as for each type

NEW ENGLAND REGION I 1973 Table 3
CARLOAD UNIT COST (IN CENTS) BY TYPE OF TRAIN AND BY TYPE of Equipment 1/, Other Than TOFC Cars 2/

LINE NO.	TYPE OF EQUIPMENT (2)	EMPTY RETURN RATIO (3)	VARIABLE EXPENSES LINE-HAUL PER CAR-MILE (4)	LINE-HAUL PER CWT.-MILE (5)	TERMINAL PER CARLOAD 3/ (6)	TERMINAL PER CWT. (7)	CONSTANT EXPENSES LINE-HAUL CWT.-MILE (8)	TERMINAL PER CWT. (9)	LI NO
	AVERAGE TRAIN								
1	BOX-GENERAL UNEQUIPPED	0.59	40,89580	0.02256	9399,055	.045	0.02413	3,133	1
2	BOX-GENERAL EQUIPPED	0.86	55.64618	0.02256	9399,055	.045	0.02413	3,133	2
3	BOX-SPECIAL	1.01	64.03397	0.02256	10095,684	.045	0.02413	3,133	3
4	GONDOLA-GENERAL 4/	0.78	47,79080	0.02256	10095,684	.045	0.02413	3,133	4
5	GONDOLA-SPECIAL 4/	1.00	55,95383	0.02256	10095,684	.045	0.02413	3,133	5
6	HOPPER-OPEN GENERAL 4/	0.86	47,50855	0.02256	10095,684	.045	0.02413	3,133	6
7	HOPPER-OPEN SPECIAL 4/	0.99	50,73506	0.02256	10095,684	.045	0.02413	3,133	7
8	HOPPER-COVERED	1.05	55,87251	0.02256	10095,684	.045	0.02413	3,133	8
9	STOCK	1.05	49,02696	0.02256	10095,684	.045	0.02413	3,133	9
10	FLAT-GENERAL	0.88	48,86378	0.02256	10095,684	.045	0.02413	3,133	10
11	REFR-MEAT-MECHANICAL	0.95	60,78661	0.02256	6632,844	.045	0.02413	3,133	11
12	REFR-O/T MEAT-MECH.	0.79	58,30298	0.02256	6632,844	.045	0.02413	3,133	12
13	REFR-MEAT-NON MECH.	0.97	55,63170	0.02256	6632,844	.045	0.02413	3,133	13
14	REFR-O/T MEAT-NON MECH.	1.00	52,86887	0.02256	6632,844	.045	0.02413	3,133	14
15	TANK-10,000 -18,999 gallons	1.08	64,48138	0.02256	6632,844	.045	0.02413	3,133	15
16	TANK-28,000 -31,999 gallons	1.08	76,21408	0.02256	6632,844	.045	0.02413	3,133	16
	WAY TRAIN								
17	BOX-GENERAL UNEQUIPPED	0.59	50,58905	0.03411	9399,055	.045	0.02413	3,133	17
18	BOX-GENERAL EQUIPPED	0.86	70,98003	0.03411	9399,055	.045	0.02413	3,133	18
19	BOX-SPECIAL	1.01	82,60030	0.03411	10095,684	.045	0.02413	3,133	19
20	GONDOLA-GENERAL 4/	0.78	59,67001	0.03411	10095,684	.045	0.02413	3,133	20
21	GONDOLA-SPECIAL 4/	1.00	70,45587	0.03411	10095,684	.045	0.02413	3,133	21
22	HOPPER-OPEN GENERAL 4/	0.86	58,79901	0.03411	10095,684	.045	0.02413	3,133	22
23	HOPPER-OPEN SPECIAL 4/	0.99	62,63710	0.03411	10095,684	.045	0.02413	3,133	23
24	HOPPER-COVERED	1.05	69,97968	0.03411	10095,684	.045	0.02413	3,133	24
25	STOCK	1.05	59,63103	0.03411	10095,684	.045	0.02413	3,133	25
26	FLAT-GENERAL	0.88	60,58549	0.03411	10095,684	.045	0.02413	3,133	26
27	REFR-MEAT-MECHANICAL	0.95	78,88878	0.03411	6632,844	.045	0.02413	3,133	27
28	REFR-O/T MEAT-MECH.	0.79	76,20126	0.03411	6632,844	.045	0.02413	3,133	28
29	REFR-MEAT-NON MECH.	0.97	70,96254	0.03411	6632,844	.045	0.02413	3,133	29
30	REFR-O/T MEAT-NON MECH.	1.00	66,58578	0.03411	6632,844	.045	0.02413	3,133	30
31	TANK-10,000 -18,999 gallons	1.08	79,13127	0.03411	6632,844	.045	0.02413	3,133	31
32	TANK-28,000 -31,999 gallons	1.08	96,86798	0.03411	6632,844	.045	0.02413	3,133	32
	THROUGH TRAIN								
33	BOX-GENERAL UNEQUIPED	0.59	39,03596	0.02035	9399,055	.045	0.02413	3,133	33
34	BOX-GENERAL EQUIPED	0.86	52,70415	0.02035	9399,055	.045	0.02413	3,133	34
35	BOX-SPECIAL	1.01	60,47169	0.02035	10095,684	.045	0.02413	3,133	35
36	GONDOLA-GENERAL 4/	0.78	45,51158	0.02035	10095,684	.045	0.02413	3,133	36
37	GONDOLA-SPECIAL 4/	1.00	53,17136	0.02035	10095,684	.045	0.02413	3,133	37
38	HOPPER-OPEN GENERAL 4/	0.86	45,43764	0.02035	10095,684	.045	0.02413	3,133	38
39	HOPPER-OPEN SPECIAL 4/	0.99	48,45143	0.02035	10095,684	.045	0.02413	3,133	39
40	HOPPER-COVERED	1.05	53,16582	0.02035	10095,684	.045	0.02413	3,133	40
41	STOCK	1.05	46,99242	0.02035	10095,684	.045	0.02413	3,133	41
42	FLAT-GENERAL	0.88	46,61476	0.02035	10095,684	.045	0.02413	3,133	42
43	REFR-MEAT-MECHANICAL	0.95	57,31337	0.02035	6632,844	.045	0.02413	3,133	43
44	REFR-O/T MEAT-MECH.	0.79	54,86888	0.02035	6632,844	.045	0.02413	3,133	44
45	REFR-MEAT-NON MECH.	0.97	52,69023	0.02035	6632,844	.045	0.02413	3,133	45
46	REFR-O/T MEAT-NON MECH.	1.00	50,23703	0.02035	6632,844	.045	0.02413	3,133	46
47	TANK-10,000 -18,999 gallons	1.08	61,67058	0.02035	6632,844	.045	0.02413	3,133	47
48	TANK-28,000 -31,999 gallons	1.08	72,25127	0.02035	6632,844	.045	0.02413	3,133	48

(Costs shown in cents per service unit)

Line No.	Type of Equipment (2)	Empty Return Ratio (3)	Variable expenses: Line-Haul Per Car-mile (4)	Variable expenses: Line-Haul Per cwt.-mile (5)	Variable expenses: Terminal Per carload3/ (6)	Variable expenses: Terminal Per cwt. (7)	Constant expenses: Line-Haul Per cwt.-mile (8)	Constant expenses: Terminal Per cwt. (9)
	Car Ownership Costs							
49	Box-general service unequipped..	xxx	10.05847	xxx	3289.696	xxx	.00161	.275
50	Box-general service equipped....	xxx	11.76652	xxx	3289.696	xxx	.00161	.275
51	Box-special service.....	xxx	12.71543	xxx	3462.839	xxx	.00161	.275
52	Gondola-general service 4/.....	xxx	11.26043	xxx	3462.839	xxx	.00161	.275
53	Gondola-special service 4/.....	xxx	12.65217	xxx	3462.839	xxx	.00161	.275
54	Hopper open-general service 4/..	xxx	11.76652	xxx	3462.839	xxx	.00161	.275
55	Hopper open-special service 4/..	xxx	12.58891	xxx	3462.839	xxx	.00161	.275
56	Hopper covered.....	xxx	12.96847	xxx	3462.839	xxx	.00161	.275
57	Stock.....	xxx	12.96847	xxx	3462.839	xxx	.00161	.275
58	Flat-general service.....	xxx	11.89303	xxx	3462.839	xxx	.00161	.275
59	Refrigerator meat mech.....	xxx	xxx	xxx	xxx	xxx	.00161	.275
60	Refrigerator Other mech.....	xxx	xxx	xxx	xxx	xxx	.00161	.275
61	Refrigerator meat non-mech.....	xxx	xxx	xxx	xxx	xxx	.00161	.275
62	Refrigerator Other non-mech.....	xxx	xxx	xxx	xxx	xxx	.00161	.275
63	Tank-10,000-18,999 gallons.....	xxx	xxx	xxx	xxx	xxx	.00161	.275
64	Tank-28,000-31,999 gallons.....	xxx	xxx	xxx	xxx	xxx	.00161	.275

Figure E-2. Samples of data from rail carload cost scales. (*Source: Ref.* E-3)

of freight car within those regions. These unit costs, which are averages, should be adequate for many systems planning purposes. However, there are some 21 additional tables and appendixes that provide further detail, allowing adjustment of tabulated unit cost data to take local conditions into account. Table E-1 lists the data available.

This brief description of Rail Form A costing and its output provides an overview of the process and principal output, and suggests the depth of detail that it is possible to pursue in establishing railroad costs. A more complete description may be found in other ICC publications (*E-4, E-5*). In addition, for motor carriers, *Highway Form B* is a 39-page workbook containing work sheets and instructions for developing costs without extensive special studies (*E-6*).

Barge Line Costs

Common and contract barge line carriers render financial and operating data to the ICC. However, these carriers are not representative of the total industry, because most waterway tonnage is carried by private or exempt carriers, who do not provide financial and operating data to the ICC. Thus, there is no public source of expense data for waterway operators comparable to the regulatory reports available for rail and motor carriers.

The ICC has barge cost formulas that it employs in regulatory rates of water carriers under its jurisdiction. These are *Water Form B* and *Barge Form C*. However, states do not have access to input data for the nonregulated water carriers, and therefore could not likely use such formulas.

The U.S. Army Corps of Engineers, which has need for barge line cost information, develops unit cost estimates through cooperation of some of the barge operators. These are not usually published, but the Corps appears willing to share them. The Office of the Chief of Engineers planned to complete during 1976 a new study of towboat capital and operating costs. Until these data become available existing data are outdated and the Corps does not want to release them.

The Corps has in an advanced stage of development what it calls its INSA Flotilla Model, part of the Inland Navigation Systems Analysis (INSA) program. The preliminary version of the model states that "the primary purpose of the INSA Flotilla Model is to determine the characteristics of a cost-effective fleet of towboats and barges required to satisfy the transfer of a given mix of commodities moving

TABLE E-1

TABLES AND APPENDIXES FROM RAIL CARLOAD SCALES

	PAGE
Table 1. Carload Mileage Cost Scales:	
New England Region	6–20
Official Territory, excluding New England Region	21–35
Official Territory	36–50
Southern Region	51–65
Western District, excluding Mountain Pacific Territory and Trans-Territory	66–80
Mountain Pacific Territory and Trans-Territory	81–95
Western District	96–110
Table 2. Carload Unit Costs for Various Weight Loads by Types of Equipment:	
New England Region	6–20
Official Teritory, excluding New England Region	21–35
Official Territory	36–50
Southern Region	51–65
Western District, excluding Mountain Pacific Territory and Trans-Territory	66–80
Mountain Pacific Territory and Trans-Territory	81–95
Western District	96–110
Table 3. Carload Unit Costs by Types of Train and By Types of Equipment:	
New England Region	111–112
Official Territory, excluding New England Region	113–114
Official Territory	115–116
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Western District, excluding Mountain Pacific Territory	119–120
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Source: Ref. *E-3*.

TABLE E-2

FREIGHT SYSTEM OPTIONS

GENERAL SERVICE	REFRIGERATED SERVICE
Rail	(17) Refr. car—Average 70-car mixed train
(1) Box car—Average 70-car mixed train	*(18) Refr. Car—70-Car run through train
(2) TOFC—Average 70-car mixed train	(19) TOFC Refr.—Average 70-car mixed train
(3) TOFC—35-car run through train	(20) TOFC Refr.—35-Car run through train
Highway—Truck load (TL)	(21) 40′ Refr. Single rig via O/D terminals
(4) 40′ Single rig direct	(22) 40′ Refr. Single rig direct
(5) 40′ Single rig via O/D terminals	
(6) 27′ Doubles rig via O/D terminals	
*(7) 40′ Doubles rig via O/D terminals	
*(8) 27′ Triples rig via O/D teminals	
Highway—Less than truck load (LTL)	
(9) 40′ Single rig via O/D terminals	
(10) 27′ Doubles rig via O/D terminals	
*(11) 40′ Doubles rig via O/D terminals	
*(12) 27′ Triples rig via O/D terminals	
Air—Container load (CL)	
(13) 4-Engine narrow-body freighter igloo system	
(14) Wide-body lower hold container system	
Air—Less than container load (LCL)	
(15) 4-Engine narrow-body freighter igloo system	
(16) Wide-body lower hold container system	

Source: Ref. *E-7*.
* Analyzed in FY 1976.

between a given set of origin and destinations and operating in a waterway network of existing or assumed characteristics." Thus, the model is a planning tool. The port-to-port algorithm consists of formulas for calculating round-trip time (in days) and costs ($ per ton-mile) for a given type of cargo between two ports. Time and costs are calculated for seven functional groups (port cargo handling, handling delay, and waiting time; tow makeup; link operations; lock operations and delays) and for towboat, barges, and cargo. Input data to the Flotilla Model include (1) waterway network data, (2) commodity type definitions, (3) transportation class definitions, (4) movement requirements, (5) port characteristics, (6) lock characteristics, (7) towboat definitions and characteristics, and (8) barge definitions and characteristics.

Towboat definitions and characteristics include, among other inputs:

- Operating cost—the average cost per day of the towboat while under way and engaged in full operations. Included are direct costs (fuel, labor, etc.) and indirect costs (administrative overhead, depreciation, insurance, etc.)
- Maneuvering cost—the average cost per day of the towboat while engaged in maneuvering operations at reduced fuel consumption rates, such as in port operations or station keeping at locks. Included are all of the operating costs except with reductions in the direct cost portion for fuel.

Although the Flotilla Model is still under development, it promises to be a very useful tool for determining the cost of commodity movement by barge.

USDOT Transportation Systems Center's Procedure for Estimating Operating Costs

Of the hundreds of studies of operating costs made over the years, most have been done by regulatory agencies or rate bureaus. Some have been extremely thorough, comprehensive, one-time studies; others are being done on a continuing basis. Most are too detailed for convenient application to statewide transportation systems planning. Recently, a macro-scale costing procedure was developed by personnel at USDOT's Transportation Systems Center in Cambridge, Mass., for use in evaluating intercity freight transportation systems within the distribution process for manufactured and perishable foods (*E-7*). The procedure covers shipments of manufactures by the rail, motor carrier, and air cargo modes.

The procedure first identifies the major combinations of equipment and door-to-door services offered by the selected modes. These system/service options are given in Table E-2. The options are then divided into several functional categories for costing purposes, such as line haul, terminal, pick-up and delivery, and overhead, which covers all other costs as well. Costs identified within each of these functional categories are then further divided into capital, labor, fuel, and maintenance components; Table E-3 gives this latter breakdown. The functional separation of costs reflects rail, motor carrier, and air carrier reporting practices to regulatory agencies.

The actual data used to derive unit costs are extracted from carrier reports to regulatory bodies supplemented by other published and unpublished data. In general, costs reflect 1974 prices and assume full capital recovery of investment at current interest rates. Average highway user

charges were included in motor carrier costs as a surrogate for highway maintenance costs. The derived cost estimates are based on average equipment types and characteristics and common carrier operating practices.

The procedure resulted in preparation of a series of tables and charts illustrating the variation in door-to-door service cost as a function of length of haul, shipment size, and density. Figure E-3 presents in summary form some of the cost data developed in the TSC study. In addition, a series of charts were developed showing door-to-door service cost for a 600-mile haul, by function, on a dollar-per-ton basis and by the cost elements of capital, labor, fuel, and maintenance on a percentage-cost-per-ton basis.

Although less detailed than the ICC approach, the unit cost figures derived by TSC have appreciable applicability to statewide freight planning. Because these are "national" figures, apparently no attempt has been made to highlight regional differences.

FREIGHT REVENUES

In preparing economic evaluations of policies or plans, detailed information is often required on the revenues earned or the rates or tariffs charged for specific freight movements under examination. The purpose of this section is to present methods available to states for obtaining revenue data pertaining to (a) railroads, (b) motor carriers, and (c) other modes.

Availability of Rate Data

Every rate of every common carrier subject to economic regulation is a matter of public record in tariffs filed with regulatory agencies. More than one-half of all highway traffic and nine-tenths of all domestic waterway traffic is not subject to regulation; therefore, public tariffs are unavailable. A 1973 ICC analysis (*E-8*) showed that 100 percent of railroad, 44 percent of motor carrier, 85 percent of oil pipeline, and 9 percent of intercity water ton-miles (including deep-sea coastwise and intercoastal) was federally regulated. Unregulated motor carriage consists of private carriage (shipper-operated trucks hauling owned goods) and exempt commodities (agricultural and seafood products, the carriage of which is exempt from regulation even when hauled by a for-hire carrier). Nonregulated water traffic consists of that moving in private carriage plus that moved by for-hire carriers under conditions that exempt it from regulation. Tows on the inland waterways and coastal

TABLE E-3

FUNCTIONAL COST ELEMENTS

TYPE OF COST	RAIL	TRUCK	AIR
Other	Wages, benefits, admin. Other admin., office exp. Cargo loss and damage Insurance Promotion and sales Billing expense Operating supervision	Wages, benefits, admin. Other admin. office exp. Cargo loss and damage Promotion and sales	Wages, benefits, admin. Other admin. office exp. Cargo loss and damage Promotion and sales
Pickup and delivery	Wages, benefits, crew Fuel, oil Maintenance, equip. Capital recovery, equip.	Wages, benefits, crew, helpers Fuel, oil, highway user charges Insurance Maintenance, equip Maintenance shop expense Salary, benefits, super. Capital recovery, equip.	Wages, benefits, crew Fuel, oil Insurance Maintenance, equip. Capital recovery, equip.
Terminal	Wages, benefits, car handling Main-terminal handling and terminal equipment Capital recovery, terminal property and equipment Fuel, terminal car handling equipment	Wages, benefits, billing, handling and other office expenses Capital recovery, terminal property and equipment Salaries, benefits, supervision	Wages, benefits, billing, handling and other office expenses Maintenance, ground property and ground equipment. Capital recovery, equip.
Linehaul	Wages, benefits, crew Fuel oil Maintenance of way Maintenance, equip. Maintenance shop expense Capital recovery, equip.	Wages, benefits, crew and helpers Fuel, oil, highway user charges Insurance Maintenance equip. Capital recovery, equip. Salaries, benefits, supervision	Wages, benefits, crew and helpers Fuel, oil Maintenance equip., maint. burden Insurance Capital recovery, equip. Aircraft service, line, control Landing fees Salaries, benefits, supervision

Source: Ref. *E-7*.

vessels carrying three or fewer bulk commodities are exempt. The net effect is that 63.5 percent of intercity ton-miles was subject to federal regulation. Thus, rate data are publicly available for less than two-thirds of all intercity freight movements.

Although tariffs with regulatory agencies contain all the rates of regulated carriers, there are so many tariffs and so many rates that this plethora of information is quite unmanageable and, in its raw form, does not normally give planners what they need, except for the narrowest of analyses where only a few rates are required. Railroad rates alone number in the millions and include 75,000 separate railroad tariffs ranging in size from a single page to more than 1,000 pages. The situation is similar for other modes.

Sheer volume alone is a barrier to use of tariffs as a source, but the problem is further compounded by the many conditions of carriage, routing rules, and other regulations contained in the tariffs which must be considered in finding the rate. In short, the applicable rate for any given movement can be found only by an expert rate clerk. Inexperienced personnel cannot find rates with any degree of certainty; the experts themselves make many mistakes. A number of small firms, called "audit bureaus," earn their livelihood by reviewing freight bills of large shippers to find errors in rates paid. Inasmuch as the only lawful rate is that published in the tariff, audit bureaus and shippers encounter little difficulty in securing adjustment from the carrier when errors are found. The audit bureau earns a percentage of all amounts saved for the shipper.

Because of the complexity of tariffs and the consequent errors in rating caused by them, a number of studies have been conducted to determine if simplification of rate systems is possible. The objective of these studies is to rearrange rates in a form amenable to computerization. This concept has been discussed since the early 1960's. Up to this point, little meaningful progress has been made in rate simplification or computerization. The present rate system is so awkward that rating errors have run as high as 34 percent (*E-9*). The total cost of rating, both in terms of the manpower required and the errors caused, has risen to the point where the interest in computerization is growing dramatically.

The large number of rates stems from the fact that almost every commodity (or commodity group) has its own "commodity rate" for each pair of points between which it moves. The class rate system, a simplified structure that

MODE	SYSTEM COSTS (1974 $/TON) 200 MILES	400 MILES	600 MILES	1000 MILES	2000 MILES	3000 MILES
GENERAL SERVICES						
Rail						
Box car-Ave. 70-car mixed train	9.04	13.42	17.86	22.42	36.02	47.46
TOFC—Ave. 70-car mixed train	18.47	26.83	35.06	42.72	65.89	85.00
TOFC—35-car run through train	14.72	18.67	22.39	30.33	49.72	—
Highway (TL)						
40′ Single rig direct	12.95	23.55	34.15	55.35	108.35	161.35
40′ Single rig via O/D term.	22	36.50	50.95	80	151.50	226
27′ Doubles rig via O/D term.	29.26	44.66	59.86	90.86	167.86	244.86
40′ Doubles rig via O/D term.	NA					
27′ Triples rig via O/D term.	NA					
Highway (LTL)						
40′ Singles rig via O/D term.	59.58	73.14	87.70	116.82	189.62	263.42
27′ Doubles rig via O/D term.	59.45	74.87	90.29	120.82	197.62	274.42
40′ Doubles rig via O/D term.	NA					
27′ Triples rig via O/D term.	NA					
Air (CL)						
4-Eng. N.B. freighter aircraft, igloo	143.97	177.34	211.69	276.10	441.51	594.83
W.B. lower hold aircraft, container	63.10	65.74	68.38	73.66	86.86	100.06
Air (LCL)						
4-Eng. N.B. freight aircraft, igloo	NA					
W.B. lower hold aircraft, container	NA					
REFRIGERATED SERVICES						
Rail						
Refr. car—Ave. 70-car mixed train	22.13	31.48	40.80	47.40	69.90	86.40
Refr. car—70-car run through train	NA					
TOFC Refr.—Ave. 70-car mixed train	32.58	46.50	61.08	73.33	111.67	142.17
TOFC Refr.—35-car run through train	23.92	29.92	35.92	48.00	78	—
Highway						
40′ Refr. single rig direct	13.90	25.30	36.70	59.50	116.50	173.50
40′ Refr. single rig via O/D term.	23.37	38.99	54.86	85.79	163.88	241.98

Figure E-3. Door-to-door system costs as a function of length of haul, in 1974 $/ton. (Source: Ref. E-7)

assigns rates to broad groupings of commodities, provides a rate for every commodity, but is used for probably less than 5 percent of rail traffic. Class rates are higher than commodity rates, the latter being tailored to particular movements. Much truck traffic (usually less than truckload) moves at class rates; but again, there is usually a lower rate available for larger movements. Commodity rates are based on market forces, which vary by commodity and origin-destination. They are, in effect, negotiated between carriers and shippers.

In broad terms, rates are conditioned by carrier costs, which set the lower end of a range, and value of service, which limits the amount a shipper is willing to pay. These are, in turn, functions of commodity transportation characteristics, volume, commodity value, direction of movement, carrier competition, market competition, distance, and other factors. Commodity characteristics refer to such factors as size of shipment, type of car required, methods of handling, special services required (refrigeration, protection from freezing, etc.) Volume, especially the size of individual shipments and cumulative amount of traffic over time, also affects carrier costs. A full truckload need not pass through a terminal, whereas less-than-truckload shipments usually require terminal handling. A multi-car shipment by rail is handled at lower unit cost per carload than a single car. Repetitive shipments permit a carrier to systemize its service, perhaps with dedicated equipment, reducing unit costs and therefore rates.

Carrier competition also fosters reduced rates. Movements for which carrier costs are identical might be priced differently owing to existence of carrier competition for one movement and lack of competition for another. Market competition refers to competition between suppliers at different locations selling to consumers at a single location. Transportation rates are frequently structured to foster market competition: California fruits and vegetables compete in New York with those originating in Florida. To secure traffic, the transcontinental railroads offer rates to permit the California traffic to compete. This kind of competition causes many anomalies in rates. It also, incidentally, presents pitfalls for planners in the development and use of rate generating models. Market competition and other trade practices create inconsistencies in distance-rate relationships and produce cross-hauling of goods in a pattern that seems irrational and is difficult to replicate in a model.

Distance, of course, affects costs and rates. Rates are generally higher for shorter than for longer hauls, but they are not proportionately higher. This results from relatively high terminal costs, which do not vary with length of haul. As the terminal cost is spread over greater mileage, the average cost per mile decreases. This effect introduces a taper in carrier costs and in the rates charged.

Direction of movement also affects rates. Where an imbalance exists in the directional flow of traffic, rates in the lighter direction may be held at relatively low levels to encourage maximum traffic so as to avoid empty back hauls.

Pricing strategy requires that each movement of traffic component pay at least the cost incurred in its behalf, defined as the marginal, or variable, cost. In addition, each movement should make a contribution to the constant costs, which are not attributable to particular traffic or movements. The amount of such contribution, above variable costs, to be exacted is limited by the value of the service. There comes a point where the traffic will not move if the rate is too high. The presence of competition also constrains the amount of markup over cost.

Compilation of Rate Data

Use Revenue Data

USRA in supporting state rail planning efforts has provided to northeastern and midwestern states, on request, copies of the magnetic tape file containing railroad traffic data on the seven bankrupt railroads for 1972. These tapes could be summarized on a commodity or commodity group basis to yield average rates, as well as the distribution of rates, on a mileage block or on an area-to-area basis. Thus, generalized rate tables could be assembled by simply processing the information contained on these tapes. This, however, is an exception; this type of detailed information is usually not available from other railroads or from other modes. Similar data are available from the ICC 1 percent rail waybill sample on a territorial and national basis, but the sample is too thin for maximum usefulness in the study of state or substate freight originating or terminating areas. Were the waybill sample to be expanded, it would provide a good source of average revenue data.

Collect Actual Rate Data

Collecting actual rate data on a large scale is a very difficult proposition at best. If, for example, county-to-county rate data were desired for a single mode in a typical state having 60 counties, a table for an individual commodity would contain $60 \times 60 = 3{,}600$ cells. Developing a similar table for, say 10 percent of the 14,500 theoretically possible 5-digit commodities that could potentially use motor carrier and rail, would yield a million individual rate entries within the state, with no data on rates for shipments made to and from other states. Such an approach is obviously not practical.

A more reasonable and feasible approach might be to develop rate information for a finite number of commodities, mostly bulk. Rates would be generated only for movement types revealed by traffic flow data. This would keep the file down to more manageable proportions and capture most of the tonnage. Nonetheless, it should be emphasized that this would be a very sizable effort even for a typical state having about 60 counties and could be justified only if very detailed planning is being done over a statewide system.

On the other hand, this type of approach would be ideal where the number of commodities would be quite limited and where accuracy and detail are important. There is little or no past precedent for this kind of study. However, without detailed work of this kind, the validity of any conclusions involving rates applied on a corridor or project basis are questionable.

Substitute Proxy Data

There are existing data sources for both rail (*E-10, E-11, E-12*) and truck (*E-13*) that reveal revenues either for groups of shipments or for individual carriers. These data can be arranged and manipulated in various ways to generate generalized rate curves.

A prototype for this method is the work by the Transportation Systems Center (*E-14*) to develop rate data as input for mode split simulation. For truck class rates, TSC obtained some actual data from the ICC archives and supplemented the rate/distance curves obtained using average carrier revenue statistics from *TRINC's Blue Book*. Because class rates are expressed as percentages of Class 100 rates, other class rates were easily estimated. Class rates were then factored down using TRINC's data to yield commodity rates. This was done by developing rate curves for each type of commodity carrier, as shown in Figure E-4. Rates for private carriers were generated in a similar manner. In this way truckload (TL) and less-than-truckload (LTL) rates were developed for selected commodities, as shown in Figure E-5.

The TSC effort is typical of the kind of results that can be obtained with limited time and staff resources. Furthermore, it avoids a massive data collection effort. The amount of detail that can be achieved is proportional to the level of effort expended. The advantage of this kind of study is that it depicts rates on an average systemwide basis fairly accurately and at a relatively low cost. The disadvantage lies in the fact that very few individual commodity rates can be described as average. In fact, there are wide extremes in freight rates which, on a local basis at least, would not be reflected in rate curves developed on a proxy basis. Other studies are under way to develop rates on an analytical basis, generally through regression analyses.

Data developed in this manner are useful for systemwide analysis in that they are relatively accurate and are factually based. Use of these data unmodified for corridor or subsystem analysis should be done with great care inasmuch as systemwide averages can not be trusted in situations where specific commodity types play a large role in rate determination.

Rate Generating Models

Several practitioners—namely, Kullman (*E-15*), Morton (*E-16*), Herendeen (*E-17*), and Samuelson et al. (*E-18*)—have attempted to describe rate structures using mathematical expressions. This approach makes good practical sense because it is easily manageable and low in cost. It also makes a certain amount of theoretical sense because rates were originally derived from formuals.

Herendeen (*E-17*) presents what is probably the most successful approach to this problem, using an individually calibrated equation for each mode and commodity classification, as follows:

$$\text{Rate} = f(C, D, \text{SS}) \qquad \text{(E-1)}$$

in which

C = commodity type;
D = distance of shipment; and
SS = shipment size.

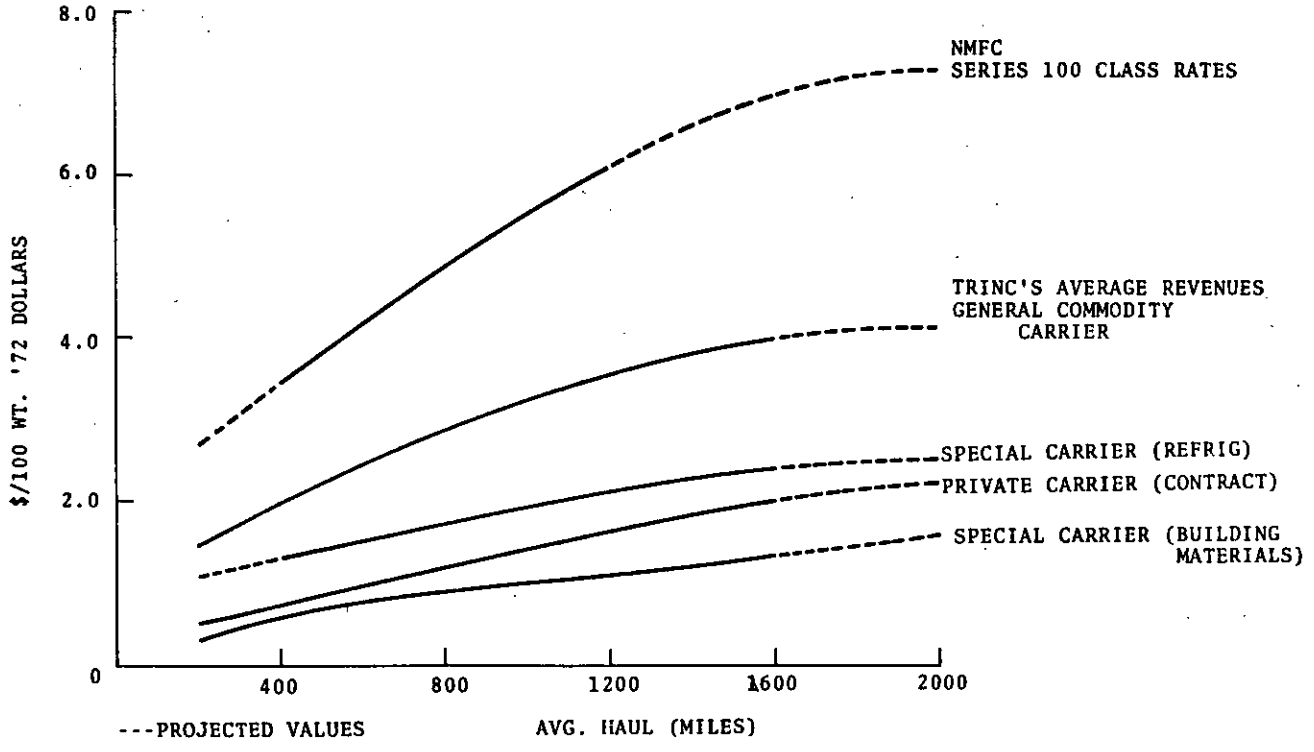

Figure E-4. 1972 Motor carrier average prices. (Source: Ref. E-14)

Mileage Blocks	General Commodities																	
	TCC 251		TCC 253		TCC 254		TCC 261		TCC 262		TCC 263		TCC 264		TCC 265		TCC 281	
	TL	LTL	TL	LTL	TL	LTL	TL	LTL	TL	LTL	TL	LTL	TL	LTL	TL	LTL	TL	LTL
200- 299	4.27	2.42	4.27	1.85	2.42	2.21	1.85	1.00	2.00	1.14	1.85	1.00	.99	1.56	1.99	2.42	1.95	1.14
300- 499	5.10	2.89	5.10	2.21	2.89	2.64	2.21	1.20	2.38	1.36	2.21	1.20	1.19	1.87	2.38	2.89	2.19	1.28
500- 999	7.12	4.04	7.12	3.09	4.01	3.68	3.09	1.66	3.33	1.90	3.09	1.66	1.66	2.61	3.32	4.03	2.82	1.65
1000-1499	9.30	5.27	9.30	4.03	5.27	4.81	4.03	2.17	4.34	2.48	4.03	2.17	2.17	3.41	4.34	5.27	3.81	2.22
1500	10.95	6.21	10.95	4.74	6.21	5.66	4.74	2.56	5.11	2.92	2.56	2.56	2.55	4.01	5.10	6.20	4.94	2.88
MIN. WT. TO QUALIFY AS TL (LBS)	15,000		15,000		12,000		24,000		36,000		36,000		36,000		15,000		30,000	

Figure E-5. Motor carrier rates, in 1972 $/100 wt. (Source: Ref. E-14)

He then chose the following functional form as best describing the data:

$$\text{Rate} = \alpha_0 D^{\alpha_1} \text{SS}^{\alpha_2} \qquad \text{(E-2)}$$

Calibrations using ICC published data resulted in multiple correlation coefficients, R^2, ranging from 0.88 to 0.92 for rail freight carload shipments and $R^2 = 0.90$ for truckload shipments. Herendeen supplemented these equations by using actual class rates for LCL and LTL traffic.

Kullman (*E-15*) formulated rail rates on the basis of linear regression equations, as follows.

$$\text{Rail rate} = \frac{500}{\text{ton}} + \text{A}_0 + \text{A}_1 \qquad \text{(E-3)}$$

in which A_0 is the average tonnage per car and A_1 is the average mileage per car.

This equation was then calibrated for each 3-digit STCC commodity. Results obtained with a linear model such as this are questionable.

Morton (*E-16*) also used regression equations, but did not calibrate by commodity. This resulted in an error too substantial for all but the most general systemwide analysis.

Samuelson et al. (*E-18*) have developed a comprehensive model relating freight rates to shipment characteristics and commodity attributes. The model takes the general form

$$\begin{aligned}\ln \text{Rate} = {} & \alpha_1 \ln \text{Miles} + \alpha_2 \ln \text{Weight} \\ & + \alpha_3 \ln \text{Density} + \alpha_4 \ln \text{Value} \\ & + \alpha_5 L + \alpha_6 G + \alpha_7 P + \alpha_8 F + \alpha_9 T \\ & + \alpha_{10} \text{Shock} + \alpha_{11} H + \alpha_{12}\end{aligned} \qquad \text{(E-4)}$$

in which

Rate = transportation charge, in cents per hundredweight;
Weight = weight of shipment, in pounds;
Density = density, in pounds per cubic foot;
Value = value per pound, in 1972 dollars at wholesale prices;
L = dummy variable for a liquid ($L = 1$ if commodity is a liquid; $L = 0$ otherwise);
G = dummy variable for a gas ($G = 1$ if commodity is a gas; $G = 0$ otherwise);
P = dummy variable for a particulate ($P = 1$ if commodity is a particulate; $P = 0$ otherwise);
F = dummy variable for freezing temperatures ($F = 1$ if freezing temperatures are required; $F = 0$ otherwise);
T = dummy variable for other temperature control required ($T = 1$ if other temperature control required: $T = 0$ otherwise);
Shock = dummy variable for shock protection required (Shock = 1 if shock protection is required; Shock = 0 otherwise);
H = dummy variable for other special handling required ($H = 1$ if other special handling required; $H = 0$ otherwise);
e = base of the natural log;
α = model parameter.

The model was calibrated with various waybill sample data for rail, truck, and water carriers. Estimation results were obtained for rail (carload and TOFC), truck (truckload, LTL, and minimum charges), and barge. Multiple correlation coefficients for these equations varied from 0.70 to 0.93.

Although the results for specific modes differ, the work shows that distance is the most important of the shipment characteristics, and value and density are the most important of the commodity attributes. Special handling requirements were not significant in any model.

These efforts indicate that attempts at developing functional rate relationships have met with mixed success. It should be noted that each of these rate functions has been used in a generalized system study of a mode split nature. For these purposes the functional description yielded sufficient precision. The same accuracy apparently can not, however, be achieved in the more detailed studies that many states will ultimately want to undertake. Moreover, with the possible exception of the rail mode, there is a lack of data necessary for calibration purposes.

Nonregulated Carriers

The foregoing options require basic rate data that are available only for regulated carriers, leaving untouched the

problem of how to deal with the unregulated carriers, who handle more than one-third of domestic traffic. Two alternatives are possible.

The first is simply to input regulated carrier rates to the private and exempt carriers by highway and water. This is the easiest method and may be suitable for some analyses, but it would tend to overstate the cost to shippers using private modes, because when exempt carriers operate for-hire their rate levels are somewhat lower than those of regulated carriers.

The second alternative would be to estimate private carrier "rates" at carrier cost plus a return to the shipper-operator. The rationale is that the shipper's cost, which is gauged by rates when for-hire carriers are used, is equated to the cost of operating his private truck or barge service plus the opportunity cost of his capital tied up in the transportation venture. Operating costs could be constructed by reference to for-hire carrier costs, but adjusted to exclude costs such as billing and terminal operations which the private carrier might not incur.

TRANSPORT TIME AND TIME RELIABILITY

Time is a major factor determining mode choice and industrial location. It is also a vital input to network analysis. These effects, which are at the heart of the freight transport system, must be accounted for in any economic analysis. The purpose of this section is to present the alternatives available to states for obtaining data on transport time and time reliability.

Basic Considerations

Definitions

Transport time is defined as the total time between that hour when the freight is on the shipper's dock ready to be loaded and that hour when it arrives at the consignee's place of business. The typical single- or multi-mode shipment might consist of the time components shown in Figure E-6, in which all of the time components are scheduled, necessary, or planned. Some studies, as reported in the following, deal only with scheduled transport time. Other studies, such as waybill studies, would also include unscheduled time as a component.

Time reliability is also a term that requires definition. Reliability is defined as the probability that the vehicle transporting goods will meet scheduled times for delivery to the consignee, that there will be no loss or damage to goods, and that the proper rate will be charged by the shipper. Time reliability is affected by a number of factors, most notably vehicle performance, company operating practices, manpower supply, amount of goods handling, weather, and vehicle supply. Time reliability can fluctuate irregularly in response to any of the factors mentioned. These characteristics make measurement of time reliability an activity that must be performed very carefully if it is to provide meaningful and accurate results.

Time and Reliability Data Attributes

It is useful to record the following items regarding time and reliability data. First, government is dependent on the

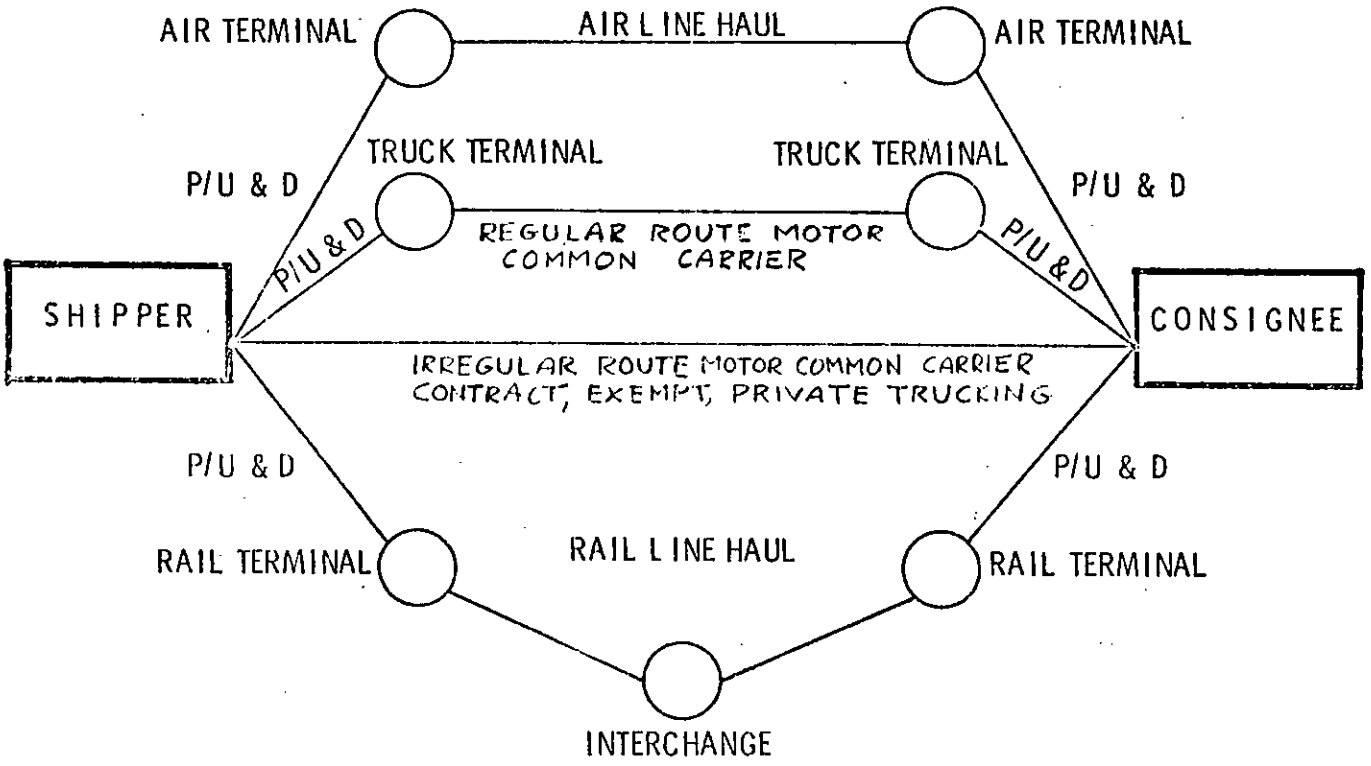

Figure E-6. Freight systems operations. (Source: Ref. E-7)

carriers for this type of information; the data can only be obtained through examining schedules or waybill records of completed shipments maintained by common carriers for a two- or three-year period after the shipment has been made. Examining common carrier records is a costly, time consuming process and no similar source of records exists for private carriers. Second, relatively few transport time and time reliability data have been collected or assembled by the public sector. Recently the Bureau of the Census used carrier records to determine transport time in a pilot study testing the feasibility of expanding the Census of Transportation. Third, large variations exist in the data, even for similar, repetitive shipments, making definitive conclusions difficult. Fourth, although great precision is not required in the data for systems applications, the number of samples required to establish point-to-point travel times for the different modal services being offered is usually quite large. However, there may be greater possibilities of data transference with this type of data than with the cost and revenue data discussed earlier.

Measuring the Cost of Time

Several analyses (*E-19, E-20, E-21, E-22*) have made reasonable attempts to determine the cost of time both for the carrier and for the shipper or consignee. In calculating the cost to the shipper or consignee, the approach taken by each of these studies is similar.

The value of time has several components. Many products deteriorate with time, thereby losing a portion of their value. There is a cost associated with having goods lie idle while in transit. The value of time is greater for those goods having a higher monetary value. The value of time is similarly sensitive to the value of money, opportunity cost, or rate of interest.

Roberts and Dewees (*E-20*) have developed a comprehensive series of formulas based on inventory theory for evaluating the cost of time for freight.

$$W_{TT} = \left(\frac{VALUE}{DT}\right) + \left(\frac{VALUE \cdot RATE}{HRSPYR}\right) + \left(\frac{VARUSE \cdot VALUE \cdot RATE}{HRSPYR}\right) \cdot PROTFC \qquad (E\text{-}5)$$

in which

VALUE = price of the commodity in the market, in dollars per shipping ton;
TT = travel time, in hours;
DT = deterioration time, in hours;
RATE = interest rate, in percent per year;
HRSPYR = hours per year;
VARUSE = percentage variation in daily commodity use that will be exceeded no more than a specified proportion of the time; and
PROTFC = one-half the number of standard deviations of daily stock use variability needed to protect against outage except for a specified proportion of the time (= 1 for 98.5 percent protection).

The third term on the right side of Eq. E-5 is an effort to estimate the value of the extra goods in inventory that must be carried to provide protection against stockout resulting from fluctuations in the use rate. Similarly, the formula for waiting time cost is

$$W_{WT} = (W_{TT} \times FACUSE) + SPACE \qquad (E\text{-}6)$$

in which

FACUSE = a factor that reduces the cost of goods during waiting; and
SPACE = the cost to provide shipping space.

Because goods may be used during waiting time, FACUSE is a factor that reduces somewhat the value of time. A third equation is needed to express the opportunity cost of goods tied up due to the reliability or variability of transit time:

$$W_{VGT} = \frac{PROTFC \cdot VALUE \cdot RATE}{HRSPYR} \qquad (E\text{-}7)$$

Table E-4 gives the relative values of these time components.

This analysis was used primarily in a prototype project, but it can easily be extended to the system, subregion, or corridor levels of planning. What differs between these levels are not the principles of transport time cost analysis, but the detail at which the study is done. At the subregional or corridor levels, time cost weighting might be generated for each transport link or for each commodity or group of commodities. At the system level, major routings might be examined on a sample basis for major commodity classes.

Charles River Associates (*E-23*) has developed a similar, but far simpler, concept of time value:

$$S_T = \frac{C\,I\,T}{(365)(24)} \qquad (E\text{-}8)$$

in which

S_T = cost per ton of transit time, in dollars;
C = the dollar cost per ton of the merchandise shipped;
I = the cost of interest risk and obsolescence, expressed as a yearly rate of interest; and
T = transit time.

TABLE E-4

COST OF TIME COMPONENTS

FREIGHT TYPE	COST: TRAVEL TIME ($/TON-HR)	COST: WAITING TIME ($/TON-HR)	COST: VAR. OF TRAVEL TIME ($/TON-HR)
Bulk	0.041	0.049	0.003
General	0.362	0.514	0.035
Special	0.00205	0.00154	0.003

Source: Adapted from Roberts, P. O., Dewees, D. H., *Economic Analysis for Transport Choice*, a Charles River Associates Research Report (Lexington Mass.: Lexington Books 1971), by permission.

For the purposes of this computation, CRA assumed an interest rate of 15 percent.

Eq. E-8 is, of course, a broad generalization and abbreviation of the previously described model, yet if it is used to represent both the transit and waiting time components, it will be in error by no more than 25 percent. This would represent a level of accuracy sufficient for generalized system studies. The model's weakness is that it does not reflect the value of time reliability, which can be a major factor. In addition, a different rate of interest must be computed for each commodity to represent perishability and risk, something which was not done in the initial CRA study.

The data requirements of the two models depend on the level at which they are being applied. Some of these data could be obtained through waybill studies. For the Roberts and Dewees model, a measurement of reliability is required, presumably from a sample of transit times. This too, although to a lesser degree, could be obtained through waybill studies where date of shipment and receipt are indicated. Also needed for the Roberts and Dewees model are estimates of several commodity-associated parameters, such as value or perishability. These can be done on a systemwide average basis.

At a subregional and corridor level, individual link and intermediate times are required for both models; however, it seems reasonable that commodity-associated data required will simply be systemwide averages.

Data for Estimating Transit Time

The essential items of data for estimating time costs are commodity value and transit time. The former is available from a number of secondary sources, whereas the latter can be derived using three different methods: (1) analytic models, (2) waybill data, and (3) link measurements. The three methods differ markedly in the level of effort required, and in the accuracy and detail derived. None of the methods has yet produced results with documented accuracy, although analytic models and waybill data have been demonstrated accurately for very generalized work. Each of the methods is described briefly in the following.

Analytic Models

Several analyses (*E-21, E-22, E-24*) have modeled rail and truck transit time on an aggregate basis. Typical of these methods is that proposed by Meyers (*E-22*) for rail:

$$T = \text{Moving time} + \text{Siding time} + \text{Interchange time} + \text{Terminal time} + \text{Local time} \quad \text{(E-7a)}$$

$$T_{\text{rail}} = \frac{m}{S_{\text{rail}}} + 0.1\left(\frac{m}{S_{\text{rail}}}\right) + \frac{m}{i_{\text{rail}}}(T_i) + m\left(\frac{T_t}{t_{\text{rail}}}\right) + L_{\text{rail}} \quad \text{(E-7b)}$$

in which

m = length of haul, in miles;
S_{rail} = average road speed by rail = 19.5 mph;
i_{rail} = average spacing between rail interchanges, in miles (= 228.5 miles);
T_i = average time spent in a single interchange, in hours (= 6 hr);
T_t = average time spent in a single terminal, in hours (= 8 hr);
t_{rail} = average spacing between rail terminals, in miles (= 140 mi); and
L_{rail} = average local delivery time for rail, in hours (= 48 hr).

A formula was similarly derived for trucks and the method could be easily extended to other modes. This is a very simple, general expression that should be employed only when aggregate analyses are being performed.

A disaggregated approach for rail shipments was taken by Martland and modified for use by Hartwig and Linton (*E-24*). Martland's original formulation is

$$\begin{aligned}\text{Mean trip time} = {} & 3.13 + 0.0007\ (\text{MILES}) \\ & + 0.51\ (\text{HUMP}) \\ & + 0.49\ (\text{FLAT}) \\ & + 0.42\ (\text{INTERCHANGE}) \\ & - 0.32\ (\text{MOVES}) \\ & + 0.45\ (\text{U})\end{aligned} \quad \text{(E-8)}$$

in which

MILES = mileage between origin and destination;
HUMP = number of hump yards traversed enroute;
FLAT = number of flat yards traversed enroute;
INTERCHANGE = number of interchanges with other railroads;
MOVES = number of moves per week of loaded and empty cars between origin and destination; and
U = measure of unreliability = 1.00 − (fraction of loads arriving in best 3-day period).

This model is theoretically more precise than the aggregate approach, but requires considerable data, most of which are unavailable or are expensive to collect. When confronted with this problem, Hartwig and Linton developed a simplified regression equation, as follows:

$$\begin{aligned}\text{Mean transit time} = {} & 125.87 - 0.40416\ (\text{miles}) \\ & + 36.91\ (\text{total yards}) \\ & + 0.00043\ (\text{miles})^2\end{aligned} \quad \text{(E-9)}$$

in which MILES represents the short line miles between origin and destination.

As the authors acknowledge, the low R^2 of 0.515 indicates that the equation would not be reliable in predicting the transit time of individual shipments. The test of the equation, for their purposes, was whether it could predict mean transit time between origin and destination. In this respect, the model did quite well.

A similar equation was developed for truck shipments, although this effort was far less successful.

One other method used to predict transit time is train performance calculators, such as those produced for the Association of American Railroads (*E-25*) and individual railroads. These models attempt to simulate the actual operations of trains at a very fine level of detail, producing results similar to those shown in Figure E-7. In these mod-

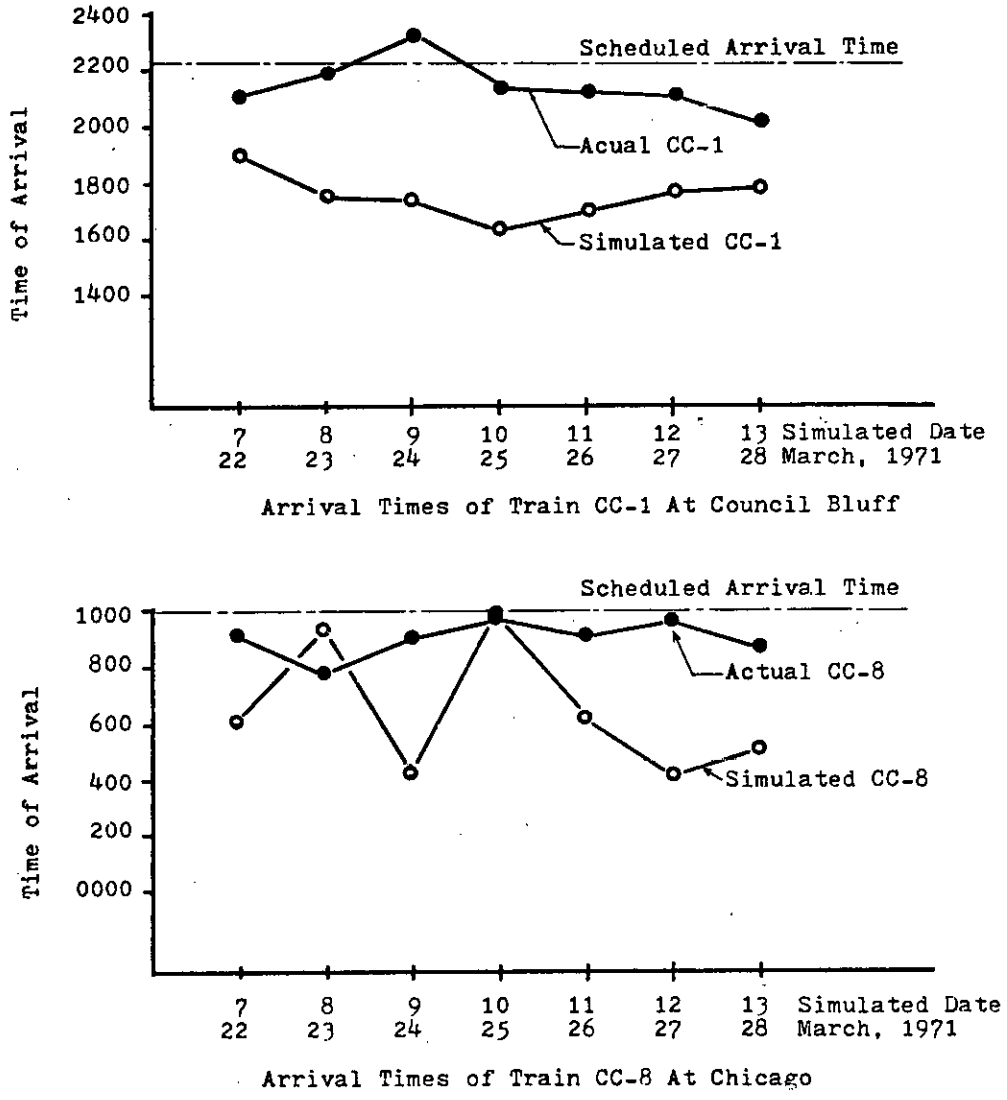

Figure E-7. Output of AAR simulation model. (Source: Ref. E-24)

els, transit time is produced almost as a byproduct. To operate these models, a large array of physical and operating data is required. Consequently, a model of this sort would not be used to generate time data unless it was simultaneously being used for other purposes.

Waybill Studies

Transit times can be obtained directly from waybills where, theoretically, both shipment and receipt dates are indicated. As might be expected, this is not always the case in practice. One study (*E-18*) found that 40 percent of rail shipments and 35 percent of truck shipments were lacking these data in whole or in part. If done as part of a small sample waybill study or a part of a major traffic flow data effort, the collection of time data alone should not entail a large expense. Unfortunately, this method of gathering time data has some weaknesses. First, as previously noted, many waybills are lacking in sufficient time data. Second, only total transit times are obtained, which may serve well to generate shipper or consignee time costs but may not be adequate for other analyses that require link time, intermediate time, etc. Third, it remains a costly, time-consuming activity that is entirely dependent on searching out historical records maintained by common carriers.

Link Measurements

Some feel that the highest precision and flexibility in measurement of shipment time would result from individual time measurement of trip components. To do this would require average time measurements along each section of track, through each yard and terminal, and at each switching point. These link measurements could then be aggregated in any fashion to yield transit time for a complete shipment. As an added benefit, reliability could be measured for each trip segment and aggregated for each shipment.

Data gathered in this fashion would have an enormous variety of uses, ranging from construction of minimum time

paths to calculation of link specific time costs. This flexibility has its price though, and it appears that for the immediate future, at least, this type of study is far too expensive for statewide systems analysis. It does, however, remain feasible for smaller subregional study.

Measuring Time Reliability

Time reliability has been identified as one of the key variables in modal choice models. The notion of reliability is based on the amount of variation that occurs around an "average" transit time. A shipment that always arrives two days behind schedule is considered reliable despite its lateness, whereas a shipment that occasionally arrives ahead of schedule is considered unreliable.

Two general approaches to reliability measurement have been suggested. The first is based on the idea that if a shipment arrives with an "acceptable" time range, say three days, it is on time or "reliable." Outside of this range, it is "unreliable." Therefore, the quantitative measure of reliability is the percentage of shipments arriving during a three-day period. To make this measurement, a fairly large number of measurements of shipments having identical origin-destination are needed. This kind of measurement does not indicate the extremes in unreliability.

An alternative measure of reliability is simply to compute the standard deviation of transport time. This is a simple calculation and can be done with fewer data points than the previous methods. Hartwig and Linton (*E-24*) calculated reliability indices for truck in trip length blocks of 100 miles, which resulted in reliability indices ranging from 1.72 to 3.63 days. Similar measurement for rail resulted in a range of from 1.42 to 4.57 days.

If transport time data are collected, they should be in a form amenable to measuring or calculating shipment reliability. No measure of reliability can be derived from the analytical models, however.

DATA REQUIREMENTS: SUMMARY AND CONCLUSIONS

The procedures for conducting economic evaluations are quite standard and well known. The challenge comes in identifying and using the right cost and revenue data. Thus, this appendix has presented a number of regulatory agency, USDOT, and private researcher methods for transforming cost and rate data into summary information suitable for application at the systems level.

Desired Capabilities

The capabilities being sought by states include among others:

- The ability quickly and accurately to measure freight system costs and revenues on a systems and/or corridor basis.
- Simplification of the tremendously complex, specialized, and difficult subject of rates or tariffs into a form usable in freight systems planning.
- Assemblage of unit cost data in a form usable for freight systems planning.
- Ability to derive measures of transit time and time reliability on a system or corridor basis.
- Obtaining essential data to prepare economic assessments showing the costs and benefits to be gained from possible governmental investment in freight transportation infrastructures and services.
- Obtaining a clearer understanding and appreciation of the key economic-related attributes of freight transportation —capital and operating costs, rates or tariffs, transit time, and time reliability.

Program Levels

Cost and revenue data requirements for the three different program levels are described as follows:

Stage I. Under this program level, the main emphasis is on assembling published information on costs, rates, and time. The purpose is (1) to become familiar with the readily available data; (2) to identify major cost, rate, and time differences between modes on a statewide or corridor basis; and (3) to gain a practical understanding of the compelxities of cost, rate, and time data. Data collection efforts under Stage I would be simply locating and assembling readily available rate and cost data, which would be taken at face value. Data would be sought from federal and state regulatory agencies, as well as from carriers operating within the particular state. States might find it desirable to construct generalized mileage-cost and mileage-rate-weight tables as part of a learning process. No detailed analytical work is contemplated at this stage.

Stage II. Under this program level, the capabilities achieved in Stage I would be extended to include assembling alternative sets of data along with an associated understanding of how the data were originally obtained, and their strengths and weaknesses. The purpose is (1) to permit choices to be made between alternative sets of cost and rate data; (2) to refine and extend previously identified information on cost, rate, and time differences between modes on a statewide or corridor basis through further detailing by commodity and type of rate or services; and (3) to gain further insight and understanding of cost, rate, and time data. Data collection efforts under Stage II include continued assemblage of cost, rate, and time data, particularly that from other than governmental sources. Other data sets would be explored and evaluated. States should construct fairly detailed mileage-cost and mileage-rate-weight tables to have the data needed for economic assessments in a convenient, ready-to-use form. Simple analytical models similar to the TSC cost curves might be developed. No field work is contemplated at this stage.

Stage III. Under this program level, the capabilities achieved in Stages I and II would be further extended to synthesize cost and rate information based on a thorough knowledge of carrier-reported data sets. Also, significant one-time or periodic analyses plus supplemental data from the carriers would be obtained on a regular basis. Under Stage III, synthesized information would largely replace the use of historically based data sets, and computerized procedures would be used to generate cost, rate, and time data.

At the same time, the increasing need to plan at finer de-

tail (particularly corridors and subareas) will require that actual rates be used for some applications. A system of coordinated data assemblage in conjunction with carriers, rate bureaus, and regulatory agencies should be initiated so that information on rates is immediately available to state DOT's. Such data are highly specialized and require the services of a rate specialist.

As freight planning approaches the point where time and reliability data are required, it may be necessary to conduct special studies to measure transit times and reliability by mode on a corridor or city-pair basis. At present such data are only available in fragmented form.

Data Required for Impact Estimation

Data required for Stages I, II, and III are summarized in Table E-5. Data requirements shown are additive, as explained previously.

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E-6. Interstate Commerce Commission, *Simplified Pro-*

TABLE E–5

DATA REQUIREMENTS FOR ECONOMIC EVALUATION

DATA CATEGORY	DATA REQUIREMENTS
	(a) Stage I
Costs	1. Average modal operating costs for selected commodities, by mileage and tonnage blocks. 2. Typical unit capital cost for selected modal investments (particularly rail).
Rates	1. Average revenue, by commodity. 2. Average mileage, by commodity. 3. Class rates.
Transport time	1. Carrier scheduled times.
Time reliability	1. None.
	(b) Stage II
Costs	1. More detailed operating costs, by commodities, by mileage blocks, by shipment size, etc. 2. More detailed unit capital costs.
Rates	1. Revenue, by shipment size [a] 2. Mileage, by shipment size [a]
Transport time	1. Waybill studies. 2. Sample surveys of total transit time. 3. Length of haul, by shipment, line-haul time, transfer time, delivery time, etc.[b]
Time reliability	1. Standard deviations, derived from samples of actual shipment times.
	(c) Stage III
Costs	1. Detailed operating cost data (comparable to that available to carriers and regulatory agencies). 2. Detailed unit capital costs, derived through studies similar to the Bechtel study.
Rates	1. Tariff schedules (class, commodity, special). 2. Tariff rules.
Transit time	1. Time, obtained through field measurements.
Reliability	1. Additional samples of actual shipment times.

[a] Derived from ICC, DOT, USRA data sources
[b] From analytic models.

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APPENDIX F

IMPACT ESTIMATION

In this appendix, a number of the analytical procedures used to estimate the impacts of changes in freight transportation infrastructure or services are presented as part of a continuing identification of the specific types of data needed for statewide freight transportation planning purposes. This appendix is the fifth and final one devoted to identifying data requirements.

In Appendix A the need for data useful in determining direct and indirect impacts was developed based on first identifying and then systematically examining important issues or problems. The results indicated a moderate need for data for impact estimation purposes. Of the ten subgroups of data identified and described in Appendix A, data in support of noise, air quality, economic, and safety-related assessments were singled out as being the most likely and frequently required. Surprisingly, data needed to support energy consumption calculations did not rank as high as was expected.

The impacts identified through the previously described examination of issues or problems turned out to be similar to the impacts examined by Battelle Columbus Laboratories (*F-21*) in their environmental assessment of the USRA's final system plan for the northeast and midwest sections of the country. Battelle evaluated the effects of the rail plan on energy, air quality, noise, water quality, and biota stemming from abandoning buildings and facilities, reducing service, consolidating and abandoning rail lines, electrification and rehabilitation, modernization and expansion of facilities and equipment. The effect of both the Battelle work and this research has been to reduce the number of potential impact analyses having significance and importance in systems-level freight planning.

The examination of supporting data needs in this appendix is restricted to items that are unique to freight transportation. Impact estimation obviously depends on traffic flow data by mode and information on the physical charac-

teristics of each plan or alternative. Of particular interest are data giving the emission and noise generation and energy consumption characteristics of various freight vehicles under different roadway, load, and speed conditions.

As indicated in Appendix A, three types of data are generally required in determining the amount and effect of impacts: (1) the physical characteristics of the routeway and the vehicles involved, including loading; (2) the unit amount or generation of the effect potentially causing an impact; and (3) ambient conditions or the base against which impact additions are evaluated. The first and third data categories are site- or facility-specific. The second type of data should apply universally.

Why are impact data so important when freight movements *per se* cause only a small portion of the air, noise, and water pollution stemming from transportation services? The answer lies in the combined set of legislative actions, international events, and economic problems, largely in the past five years, that collectively have established national environmental and energy policies. Passage and implementation of the National Environmental Policy Act of 1969 has focused attention on air, noise, and water pollution impacts, while the limits of energy resources were clearly demonstrated in the oil embargo during the winter of 1973.

Also, FHWA Action Plan requirements mandate that states follow an orderly, systematic process in developing plans and projects that take environmental concerns into full consideration. Because impact assessment has become an integral part of the transportation planning process, it is obviously desirable to identify impact-related data requirements needed in freight planning beyond those already available as a consequence of routine highway planning (e.g., noise generation data for heavy trucks as a function of speeds and gradients are already available to state DOTs).

Through the use of empirically derived constants and equations, most methods transform traffic flow and other types of consumption or emission production, by mode, into a set of anticipated impacts. Impacts are usually calculated separately for each mode and then combined to obtain total impacts for a given plan or alternative. The level of sophistication of available methods varies appreciably; more sophisticated methods utilize more types of and more detailed data on the characteristics of physical facilities and simulate actual operating conditions more closely.

Only primary impacts have been considered in this appendix; this includes direct effects (change in pollutants generated or energy consumed on the mode being considered) as well as indirect ones (effect of changes in service or use of one mode on all the others). Secondary impacts are not considered. An example of the latter is the energy required to manufacture vehicles.

Appreciable effort has been devoted in this appendix to identifying methods and data needed for energy consumption calculations. This reflects an expectation that this particular impact will become increasingly important in all phases of transportation systems planning. The techniques for determining energy consumption impacts are not as well known to state DOTs as the techniques for computing air, noise, and water pollution impacts. Of the 21 states that had NEPA-type legislation, eight require that selected aspects of the direct energy requirements of proposed projects be analyzed (*F-12*). The emphasis on energy consumption also reflects the fact that in freight planning, significant opportunities do exist for making modal and service trade-offs if energy conservation becomes a preeminent state-level or Federal policy.

ENERGY CONSUMPTION

Transportation activities in the United States consume about 25 percent of the total energy used and more than 52 percent of the petroleum products used. Freight movement accounts for roughly 25 percent of the total transport energy or nearly 5 quadrillion (10^{15}) Btu (5 274 quadrillion joules) of energy per year (*F-8*). Total energy consumed by freight movements is stated in British thermal units (Btu) or joules, because of variations in the amounts of energy obtained from different types of fuel.

Energy consumed in moving freight is a function of a large number of physical parameters associated with the commodity being carried, the vehicle, the route, and the operating environment. Table F-1 gives the important factors affecting energy consumption for the different modes. Obviously the importance of the individual factors varies appreciably among the different modes.

Accounting for all of the factors given in Table F-1 would be extremely costly and would require massive amounts of data collection to obtain physical and operational parameters. The actual computations are entirely straightforward and feasible to perform on a regional or statewide basis; but, because of the cost, simpler methods dealing with fewer factors have tended to be used for statewide freight planning purposes.

There is a discernible shift toward more comprehensive methods that would be of value in freight statewide systems planning. USDOT, in its work in support of Project Independence (*F-2*), developed a detailed model to simulate coal movements in the United States. The energy calculation methods used were not unique but the over-all model was noteworthy in that a total energy balance between modes was attempted.

Simulators, such as railroad performance calculators, have been developed in recent years by a number of the larger carriers to measure performance along a particular rail line under different operating environments. Although such simulators were originally developed to estimate time and operating costs, they can readily be used to calculate energy consumptions, because energy is simply one of the cost components. The U.S. Army Corps of Engineers is developing a similar tool to measure performance on the nation's waterways. Although the researchers are not aware of any simulators *per se* for the motor carrier industry, such capability could be achieved simply by extending statewide traffic assignment models to include routines for calculating energy consumption. The difficulty lies not in the computations themselves but in data needed on highway system geometrics, truck loadings, and the composition of the truck fleet. A number of states already have detailed curvature and gradient data in their highway information or characteristic files for routes on the state highway system. On the

TABLE F-1

FACTORS AFFECTING FUEL CONSUMPTION

MODE	VEHICLE-RELATED FACTORS	ROADBED AND OPERATIONAL FACTORS	LOAD FACTORS
Rail	Size and weight of the rail car (ratio of net to gross tonnage). Type and size of the locomotive. Fuel consumption rate in gal per hp-hr (litre per kilowatt) or gal per ton-mile (litre per metric ton-kilometre).	Number of trains operated. Track profile and curvature. Maximum operating speed. Number of slow orders. Sections having reduced speeds.	Train size. Mix of empty and full cars. Commodity weight carried per car. Ton-miles (metric ton-kilometres) shipped, by commodity type. Empty return ratio. Commodity weight carried per truck.
Truck	Type and size of truck. Fuel consumption rate in gal per hp-hr (litre per kilowatt) or gal per ton-mile (litre per metric ton-kilometre).	General route profile. Average operating speed. Number of stops required. Number of speed changes.	Empty/return ratio. Commodity weight carried per vehicle. Ton-miles (metric ton-kilometres) shipped, by commodity type.
Port/ inland waterway	Type and size of vessel. Condition of hull. Fuel consumption rate in gal per hp-hr (litre per kilowatt) or gal per ton-mile (litre per metric ton-kilometre).	Speed of river currents (upstream and downstream). Vessel operating speed. Circuity between origin and destination.	Empty return ratio. Commodity weight carried per vehicle. Ton-miles (metric ton-kilometres) shipped, by commodity type.
Air cargo	Type and size of aircraft. Fuel consumption rate in gal per hp-hr (litre per kilowatt) or gal per ton-mile (litre per metric ton-kilometre).	Operating speed restrictions. Reserve fuel requirements.	Proportion carried in passenger aircraft. Empty/return ratio. Commodity weight carried per aircraft. Ton-miles (metric ton-kilometres) shipped, by commodity type.
Pipeline	Diameter of pipe. Type and size of pumping stations. Fuel consumption rate in gal per hp-hr (litre per kilowatt) or gal per ton-mile (litre per metric ton-kilometre).	Velocity of fluid. General route profile.	Viscosity of fluid carried. Ton-miles (metric ton-kilometres) shipped, by commodity type.

other hand, most states have fairly meager vehicle classification and truck flow data. Developing such a simulation capability represents a long-term goal for systems planning.

Methods of Computing Energy Consumption by Rail and Motor Carrier

In this section, the simpler methods for computing energy consumption for the rail and motor carrier modes are presented first, Then train performance calculators, which represent the most sophisticated tool for computing energy consumption in common use today, are discussed. Methods for computing energy consumption by inland waterways, pipeline, and air, which are far less advanced, are summarized in a later section.

National Averages

Type of Method. A number of investigators (*F-5, F-7, F-11, F-14, F-16*) have developed average values for energy consumption expressed in Btu's or gallons per ton-mile (joules or litres per metric ton-kilometre). These estimates of energy intensiveness (with associated references) are given in Table F-2.

General Formulation. As an example of methods based on national averages, PMM and JFA (*F-5*) calculated fuel consumption for both rail and truck by equating fuel consumption with resistance to motion in pounds per net ton. A graph relating resistance (R), speed for TOFC, truck and box car loads was included in their study report. After including a conversion for engine efficiency, their equation became:

$$\text{Gallons (diesel)}/1{,}000 \text{ net ton-miles} = R \times 0.2226 \times \left(1 + \frac{1}{e^{S/20}}\right) \quad \text{(F-1)}$$

where S is the speed in mph. Empty return rates were also considered.

Application of Method. Using this method, a test case was performed using parameters of: net load, 20 tons (1.8 trailers/flat car); empty return ratio, truck = 0.15, rail = 0.4; distance, truck = 500 miles + 10 miles drayage, rail = 550 miles + 20 miles drayage. The results from this test case indicate that trucks would consume approximately 129 gal (488 litres) of fuel, TOFC 62 gal (235 litres), and rail 42 gal (159 litres).

Data Requirements. Requirements are essentially net ton-mile (metric ton-kilometre) data by mode and average load factors.

Evaluation of Method. The results from the case illustrated are important in that they demonstrate the practi-

TABLE F-2

ESTIMATES OF ENERGY INTENSIVENESS FOR DIFFERENT MODES

MODE	ENERGY INTENSIVENESS (BTU/TON MILE)[a]					
Railroad:				700(5)	680(7)	750(14)
Intercity at max. payload of 1,000 tons	550(16)					
Intercity at max. payload of 7,000 tons	330(16)					
Intercity freight		670(11)		500(5)	500(7)	
TOFC				700(5)		
Short fast train				1,430(5)		
Truck:				2,800(5)	2,800(7)	2,400(14)
Intercity at max. paload of 25 tons	1,110(16)					
Intercity at max. payload of 14.3 tons	2,023(16)					
Intercity freight		2,800(11)		1,900(5)	1,870(7)	
Barge:						500(14)
Domestic waterway freight		680(11)		500(5)		
Mississippi system			570(29)			
Pipeline:						
Oil only		450(11)		600(5)		1,850(14)
Aircraft:				42,000(5)		63,000(14)
Turbo fan, narrow body [b]	9,100–14,700(16)					
Turbo fan, wide body [b]	7,700–9,000(16)					
Intercity freight		42,000(11)				

Note: 1 Btu/ton-mile = 723 joules/metric ton-kilometre.
[a] Numbers in parentheses are reference sources from this appendix (F).
[b] Varying payload and trip length.

cality of this method for "ballpark" estimating. Similar calculations can be quickly made using a variety of assumptions.

If ton-miles (metric ton-kilometres) of local and intercity travel were known, better figures for total Btu's (joules) consumed could be obtained. Estimates made using national averages do not consider variations in energy consumption due to the terrain traversed, the densities of commodities carried, the types of vehicles used, or the amount of deadheading required.

Estimates of energy intensiveness (EI) should not be used directly to compare the efficiency of different modes because of variations in route length, vehicle net to gross ton (metric ton) ratios, and roadbed characteristics. However, they can be used to convert ton-miles (metric ton-kilometres) by mode into energy consumption.

Resistance Equations (Applied to Rail Branch-Line Abandonment Situations)

Given more detailed descriptions of freight flows by commodity type, more precise estimates of energy consumption can be made. A number of techniques of this type have been used or proposed for analysis of branch-line abandonments (*F-4, F-21, F-24, F-25*).

Type of Method. As an example of resistance equations applied to branch-line abandonment, RCAI and RLBA (*F-25*) made detailed calculations of energy consumption based on roadbed and vehicle physical characteristics and shipper surveys to compute energy consumption for branch lines in Pennsylvania.

General Formulation. The tractive effort required to move freight over a branch rail line was calculated using

$$TE = \pm 70(V_1^2 - V_2^2) + (R + 20G + 0.8D) \qquad \text{(F-2)}$$

where

TE = tractive effort required (lb/ton);
V_1 = initial train speed (mph);
V_2 = final train speed (mph);
R = train resistance (lb/ton) at selected speed;
G = grade, from track charts (percent); and
D = degree of curvature, from track charts.

The tractive effort describes the work that must be expended by the locomotive to pull the train. Given the weight of a train, the total tractive effort required can be calculated. This was then converted into horsepower-hours, from which total fuel consumed was calculated using an average rate of 0.06 gal/hp-hr. Fuel used in switching operations was calculated by assuming that 0.75 gal of fuel was used for each car switched.

For trucks, fuel consumed between the plant and the nearest railhead of the trip was calculated using the weight of the commodity carried and the type of terrain traversed. Terrain was classified as level, rolling, or hilly. Assumptions were also made to describe the number of stops required and the average speed (35 mph was used). Equations of the following type were then developed and applied for each commodity carried:

$$\text{Fuel consumed} = \frac{d}{(K - M\,x)} + \frac{C\,d}{K} \qquad \text{(F-3)}$$

where

K = the fuel consumption rate of an unloaded truck on various types of terrain (*F-26*);
C = empty-return ratio; 1.00 was used for branch-line movements and 0.25 for mainline movements;
M = constant applied to x to account for fuel consumption on various types of terrain;
x = commodity weight; and
d = one-way distance traveled.

For the mainline portion of the haul, the same type of equation was used; however, no allowance was made for the type of terrain traversed.

Application of Method. In applying this method in Pennsylvania several steps were necessary in developing commodity flows, determining the future mode, and calculating the number of trucks required. From a survey of branch-line users, the amounts and types of commodities carried by a rail line being considered for abandonment were estimated, including the origin and destination of each shipment. Future modes were identified based on stated user preference. The choice lay between all-truck and truck to the nearest railhead and rail for the remainder of the shipment. ICC statistics (*F-27*) were then used to convert commodity flows to truck movements using the average weight carried per truckload for each type of commodity. The energy consumed by the added trucking was then computed.

Data Requirements. Data required for line-specific calculations of energy consumption included (1) the net weight and the origin/destination of freight shipped or received, (2) the number of trains operated per week, (3) track charts showing curvature and gradient, (4) average operating speeds, (5) general grade of the highway routes, (6) average rail car and truck loadings by commodity type, and (7) fuel consumption rates for trucks and locomotives.

Evaluation of Method. Techniques such as the one described are useful and accurate for determining energy consumption along specific routes. However, the results obtained must be studied in their proper context. Based on the work conducted in Pennsylvania, energy consumed on the branch-line portion of a movement represented less than 5 percent of the total energy consumed. These methods offer quantitative results for the specialized analysis of branch-line abandonments; more generalized methods are needed to deal with statewide energy impacts of freight plans.

Propulsive Work Calculations

Morlok (*F-22*) and Hopkins (*F-23*) used engineering and physics principles to calculate propulsive work requirements for line-haul truck and rail movements. The models proposed consider the relevant physical mechanisms of energy dissipation. Energy requirements for rail, truck, and TOFC mainline movements were analyzed by Morlok. Hopkins compared the energy use of trucks and rail for branch-line movements and also calculated energy consumption for different types of mainline rail movements. Although the work has been theoretical, realistic parameters of load size, distance, and route profiles have been used. Each process used a fairly complex set of mathematical relationships to describe the work required.

General Formulation. Equations were developed by Morlok (*F-22*) to describe the work required to move rail or truck freight over routes with both level and undulating profiles. The work required over level profiles was dependent on the distance traveled, the velocity, and the resistance. Resistance depends on the weight of the car, the velocity of the train, the weight of the shipment, and the cross-sectional area of the locomotive. Total resistance was calculated using standard procedures explained by Hay (*F-10*). The initial equation for undulating profiles was more complex and considered the length and percent of the grade (up or down) and the difference in elevation as well as the velocity and weight of the train or truck. This equation was simplified by considering the net effect of both up and down grades, which in many cases compensate for each other in terms of energy. If the origin and destination elevations are similar, the equation for level terrain is used. It should be noted that this general conclusion does not apply if a ruling grade makes it necessary to add another power unit to a train.

Hopkins (*F-23*) included a more comprehensive set of factors in his analysis of propulsive work required. Included in the equation were factors similar to Morlok's for line-haul and grade operations. In addition, the impacts of curves, engine efficiency, and idle conditions were included.

Application of Method. Morlok used the equations he developed to compare the work required by different modes to move freight weighing 40,000 lb and 100,000 lb for 100 miles by rail, TOFC, or truck. The effects of speed (25 mph and 55 mph) and grades (1.0% and 2.0%) were also included. He concluded that truck was the least affected by undulating profiles; the difference between work expended for truck and TOFC movements at comparable speeds is small; the lighter the load the more favorably truck compared to rail.

Hopkins applied the equation developed to a number of mainline and branch-line examples, using computer programs to perform the routine calculations. The branch-line analysis developed a group of useful curves that relate net load carried (in tons) to fuel consumption rates for rail and truck movements. The curves show the impact on fuel consumption (in lb/ton-mile) of different operating conditions, grades, locomotive power ratings, and speeds.

In the analysis of mainline rail movements, the following simplified equations were developed from the basic resistance equations using a set of assumptions:

$$F_e = 717\,F_1 \qquad \text{(F-4a)}$$

or

$$F_e = 179\,(1 + 2\,F_1) \qquad \text{(F-4b)}$$

where F_e is fuel efficiency, in ton-miles/gal, and F_1 is load factor as a fraction from 0.35 to 0.7. More precise estimates were made for various grades, speeds, and power-to-weight ratios. The results from these tests are graphed in Hopkins' report.

Data Requirements. Data needed to calculate propulsive work in the equations developed by Morlok and Hopkins

include (1) load factor, (2) grades (ruling grade only for Morlok), (3) curves, (4) power units used, (5) speeds, (6) mix of car types, and (7) ton-miles (metric ton-kilometres) shipped.

In addition, Hopkins used a fuel consumption rate of gallons per horsepower-hour (litres per kilowatt-hr) to convert propulsive work to fuel consumption. Morlok did not think that adequate data were available to convert propulsive work to fuel consumption.

Evaluation of Methods. Morlok's approach considered fewer variables and only estimated propulsive work. No conversions were made to obtain actual fuel consumption. Hopkins did develop fuel consumption for both rail and truck movements.

Hopkins also presented a wider range of situations. If commodity flows were available for a given system plan, the simple equations developed could be used to estimate fuel consumption quickly and directly. A load factor for each commodity could be calculated from average density values and the weight and cubic capacity of rail cars used to haul that commodity. This value could then be modified by a factor to represent the percentage of empty cars carried by the average train.

More precise estimates could be made for various grades, speeds, and power-to-weight ratios. By using the curves or a computer program developed from the equations, a state DOT could easily model the energy impacts of alternative rail and truck systems. However, simplifying assumptions would have to be made to account for the mix of cars in the typical train, the general characteristics of grades, and the power units used.

Empirical Estimates

Type of Method. Energy consumed on specific segments can be estimated by using historical operating results and new measurements. Changes due to increased or decreased volumes can be accounted for by factoring.

General Formulation. Rail fuel consumption in branch-line operations in Wisconsin (*F-1, F-24*) was estimated by using

$$C = \sum_{i=1}^{8} \frac{D}{S} t_i c_i \qquad \text{(F-5)}$$

where:

C = total fuel consumed, in gallons;
D = length of branch line, in miles;
S = speed of locomotive, in mph;
t_i = percentage of time in each throttle position; and
c_i = gallons per hour consumed in each throttle position.

This estimate was supplemented by estimates of the fuel consumed in switching operations.

Similarly, Cope (*F-20*) used actual test tractor-trailer combinations running over a specified route with a constant load to determine fuel consumption rates at different speeds. The methodology used was straightforward; standard test equipment and vehicles were used. In addition to speed changes, driving procedures were varied to see what impact this would have on fuel consumption. This approach provided useful route specific data. The impact of different loads could be generalized from the specific data obtained.

Application of Method. The Wisconsin method was applied to study ten sample branch lines scheduled for abandonment in Wisconsin. The method is moderately costly and requires detailed analysis because of the wide variation in branch-line characteristics. Cope used results obtained by running six different truck combinations over two Interstate routes in Virginia at different speeds with a constant load.

Data Requirements. For rail computations, the line specific data required include (1) number and type of locomotives used, (2) length of the line, (3) average operating speed, (4) percentage of time each locomotive is operated in each throttle position, and (5) gallons (litres) of fuel consumed each hour by type of locomotive and throttle position.

The study by Cope was purely empirical; the only specific data reported were the characteristics of the trucks used in the study and the characteristics of the terrain traversed.

Evaluation of Method. The Wisconsin method is primarily applicable to branch-line analysis; therefore, it has only limited usefulness for statewide analysis. If the method were used for a more general analysis, it would be difficult to obtain the required quantity of input data. It is difficult to use this type of fine-grained analysis to study statewide changes in freight systems. Nevertheless, if the input data and energy calculation equations had been programmed for computer use, it would be a workable process.

The type of experimental procedure used by Cope could be useful in statewide planning applications to (1) validate theoretical procedures for estimating fuel consumption and (2) empirically determine the influence of proposed speed changes and the most efficient operating practices. However, it would obviously be impossible because of excessive time and cost to undertake this type of test on a system basis.

Train Performance Calculators

Type of Method. Many railroads have developed detailed computer programs to simulate the performance characteristics for trains having varying trailing loads over different sections of their systems. These programs, referred to as "train performance calculators," either have been developed independently or represent a modification of existing programs developed for the Association of American Railroads.

General Formulation. Train performance calculators use route-specific inputs such as track profiles (horizontal and vertical), speed restrictions, signalization/opposing train data, maximum speeds, locomotive and freight car weight and operating characteristics, and train resistance equations to calculate the fuel consumption for different train consists. TPC charts are produced that show the total running time over a subdivision against the weight-to-power (W/P) ratio used. Fuel consumption is shown by a single curve read in gallons per 1,000 horsepower (nominal) corresponding to any running time or W/P ratio (*F-17*).

Application of Method. Various specific problems of interest to railroad management have been studied using the

TPC programs, including analysis of signal spacing, motive power scheduling, running times (with possible variations for different power and trailing weight combinations), and terminal management strategy (*F-28*). Of particular interest to state agencies are the TPCs developed by the St. Louis-San Francisco Railway Company and the Southern Railway Company. If assumptions about average train size and characteristics can be made using commodity flow data, it is possible to compute minimum running times and fuel requirements for a given train operating over a track segment. For the Southern system, track profiles and speed restrictions are maintained on tape for the entire system and the appropriate information is available for input into the TPC.

Data Requirements. As noted, train performance calculators are route-specific; therefore, if a TPC is available, the only information required for its operation is commodity flow data, speed, consist of trains used (probably different characteristics for different commodities), and empty-return ratios.

Evaluation of Method. This type of data base and processing capability is invaluable in the calculation of fuel consumption on a statewide basis. Initial contacts with the railroads operating in a state should determine whether TPC capability exists, what portions of the system are covered, what administrative arrangements can be made by the state DOT to utilize the programs and data base, and what data are required to make the program applicable statewide. By gaining access to a TPC, a state DOT can save a great deal of primary data collection effort while at the same time gaining greater accuracy in their estimates of fuel consumption for alternative freight rail plans. It is generally more efficient for states to contract with railroads for providing such services rather than to attempt to develop the capability internally.

Performance calculators either have not been developed or have not reached similar sophistication for the other freight modes. The U.S. Army Corps of Engineers is presently developing a "Flotila" model that would simulate operating costs and performance on the inland waterway system. Simulators for the other modes are proprietary tools developed by individual carriers for internal purposes.

Methods for Computing Energy Consumption by Other Modes

There are three other modes—ships and barges, pipelines, and aircraft—available for moving freight. The limited data available on energy consumption for these three modes are described in the following.

Waterborne Freight

Types of Methods and Applications. Research on the energy consumed in moving waterborne freight is not as extensive as that devoted to rail and truck freight movements. Hirst (*F-11*) has cited an average energy intensiveness of 680 Btu/ton-mile (491 640 joules/m ton-km) as suitable for order-of-magnitude estimates. This estimate was based on information compiled by Mooz (*F-18*).

A detailed listing of energy intensiveness by Sebold (*F-29*) gives a range of values between 415 and 680 Btu per ton-mile (300 045 to 491 640 joules/m ton-km). In his study, he compared the actual energy intensity of rail and barge movements in the Mississippi Corridor. He used the following procedure, which accounted for the difference in circuity between the two modes:

1. Estimate existing barge commodity flows in 290 origin-destination pairs.
2. Locate rail routes that would serve as substitutes and estimate the mileage of rail and barge routes between the 290 O-D pairs using *Rand-McNally Handy Railroad Atlas* and *1972 Interstate Port Handbook.*
3. Determine individual energy intensity for each rail line used through personal communications with ICC officials and use of ICC *Transport Statistics in the United States.*
4. Calculate total ton-miles that would be moved by substitute rail and those actually moved by barge.
5. Convert barge ton-miles to rail ton-miles to account for circuity.

The results of the study showed that to move the same amount of freight between the same origins and destinations in the Mississippi Corridor, barge was less energy-efficient than rail because of greater circuity. This illustrates the importance of circuity in any comparison of energy intensity between modes. It also illustrates that even an analysis made using average energy intensiveness factors can be meaningful when they are applied to actual route and freight movement data.

More detailed calculations can be performed using the equation for resistance found in Hay (*F-3*) to calculate propulsive work. Using this equation, a model could be developed that would calculate horsepower requirements for different commodities in different types of vessels.

Data Requirements. If energy intensiveness values are used to calculate energy consumption, the only data required are the ton-miles (metric ton-kilometres) shipped, which can be obtained from commodity flow information. If a more complex analysis is performed using the resistance equations, information would be required on (1) the type and size of the vessel, including displacement, wetted length of hull, friction factor, and cross-sectional area, and (2) operating speed and speed of current.

Evaluation of Methods. The simpler calculation methods using energy intensiveness san be readily applied to obtain statewide "ballpark" estimates of energy use. More precise estimates using the resistance equations are more difficult to perform because no methods are currently available to convert horsepower-hours to fuel consumption for marine power plants. Recently the Energy Research and Development Administration (ERDA) let contracts to study the "energy use patterns" of the "ship transport sector." The research will study the energy intensiveness of different types of vessels carrying different types of freight for typical duty cycles (*F-30*). The results of this research will be useful for states interested in measuring energy consumption on waterways.

Pipelines

Types of Methods and Applications. In 1970, pipelines accounted for 20 percent of intercity freight traffic and about 1 percent of transportation energy used. On a national average, pipelines used from 450 to 1,850 Btu per ton-mile (325 350 to 1 337 550 joules/m ton-km). Peat, Marwick and Mitchell (*F-5*) suggests using a value of 600 Btu per ton-mile (433 800 joules/m ton-km). As this wide range of values indicates, there are many factors (including pipe diameter, fluid velocity, and viscosity) that have a significant effect on the energy intensiveness of each specific pipeline. A more specific analysis can be conducted using the resistance equations developed by the oil and gas industry explained in Hay (*F-3*). The flow must be classified as streamlined or turbulent and then the proper equations must be used for the type of flow identified. The results are stated in pressure loss per length of pipeline, a loss that must be compensated for by the addition of extra energy at pumping stations. The wide range of values possible is indicated in Table F-3, developed by Hirst (*F-11*).

Data Requirements. Simple analysis of energy consumed in pipeline movements can be conducted using only the commodity flow data. A more precise analysis can be made using the values calculated by Hirst if the pipeline diameter, the viscosity of the fluid, and the velocity of the fluid are known. To use the resistance equations would require the pipeline diameter, the fluid velocity, the fluid density, the fluid viscosity, and the length of the pipeline (with elevation changes noted).

Evaluation of Methods. Detailed methods to calculate energy requirements for pipeline movements have been developed by the oil and gas industry. These methods provide information on the amount of work required to move liquids in pipelines. Unfortunately, they are very site-specific and many require more data than are available for statewide planning. More general methods may result from research being conducted for the Energy Research and Development Administration. This research should provide more general energy calculation procedures for pipeline movements (*F-30*).

Air Freight

Types of Methods and Applications. Freight moved by air represents less than 1 percent of the total freight movements, yet it consumes a more significant amount of the transportation energy used for freight movement. The exact amount of energy consumed can not be clearly stated because air freight is hauled by both cargo and passenger aircraft. No satisfactory method is available to allocate fuel to freight movement on flights that carry a mix of passenger and freight traffic. In terms of value, about 57 percent of the total air freight movements are carried by passenger aircraft. By using a set of assumptions that prorates passenger and baggage weight with freight weight, Hirst (*F-11*) developed an average measure of 42,000 Btu per ton-mile (30 366 000 joules/m ton-km). For freight carried by cargo aircraft, the average energy consumed was 27,000 Btu per ton-mile (19 521 000 joules/m ton-km).

This method does not consider the major variations in fuel consumption that exist between the various types of aircraft. Mays et al. (*F-13*) considered these differences along with others in the methods used to report airline freight movements and fuel consumption statistics. They measured freight movement distances in payload great-circle miles, which is the product of the weight of the shipment times the shortest distance (as measured in great-circle miles) between the two points. This is the generally accepted measure used by airlines to record distance measurements. Comparisons were made of the relative efficiencies of various modes in moving low-density freight. The general conclusion is that air freight carried in the average air freighter used seven times as much energy as express trains and four times as much as trucks.

Data Requirements. Estimates of energy consumed by

TABLE F–3

PIPELINE ENERGY INTENSIVENESS [a]

PIPELINE DIAMETER (IN.)	FLUID VELOCITY (FT/SEC)	ENERGY INTENSIVENESS (BTU/TON-MILE) [b] KEROSINE (0.00001 FT/SEC)	CALIFORNIA CRUDE OIL (0.000075 FT/SEC)	LIGHT ENGINE OIL (0.0005 FT/SEC)
8	3	180	290	460
	6	590	960	1500
	9	1330	1860	2870
20	3	60	90	140
	6	220	310	490
	9	450	660	980
32	3	30	50	80
	6	130	170	270
	9	260	360	540

Source: Hirst (*F-11*).
Note: 1 Btu/ton-mile = 723 joules/metric ton-kilometre.
[a] Assumes 29.5 percent efficiency in delivering energy to motor and 80 percent efficiency of the motor-pump set.
[b] At 80° F.

air movements can be made if commodity flows by air are available. More precise estimates are possible if the actual mix of freighter and passenger aircraft hauling freight is known. In addition, the aircraft duty cycles should be considered, with penalties for terminal and enroute maneuvers, reserve fuel carried, and operation speeds.

Evaluation of Methods. The amount of freight carried by air is very small and specialized when compared with movements by truck, rail, pipeline, and water. Detailed estimates of energy consumption may not be particularly meaningful because of this small volume. Use of nationwide averages does not produce satisfactory results because of the unique characteristics of air freight movements, but the more detailed process described by Mays (*F-13*) may require more specific data than are available for statewide planning.

AIR POLLUTION

The emissions that contribute to air pollution range from highly toxic gases at one extreme to minute solid particles and to relatively harmless discharges (water vapor). The five primary pollutants are carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NO_x), sulfur oxides (SO_x), and particulates. On a national scale, pollutants from internal combustion engines (used primarily for transportation) are responsible for more than 70 percent of the carbon monoxide, 56 pecent of the hydrocarbons, and 50 percent of the nitrogen oxides (NO_x as NO_2). Relatively minor contributions are made to total particulates (2.5 percent) and sulfur oxides (3.4 percent) from transportation sources. On a statewide basis, consideration of the first three pollutants is usually adequate in analyzing alternative freight system plans.

The harmful characteristics of each pollutant have been extensively documented (*F-37, F-38*). Suffice it to say that carbon monoxide is an extremely poisonous gas; it is fatal in concentrations of 1,000 ppm or greater. Oxides of nitrogen and hydrocarbons are not as inherently dangerous, but when combined in the presence of sunlight they combine in a photochemical process to produce smog.

The Clean Air Act Amendments of 1970 are the most comprehensive Federal regulations dealing with air quality. They require that states measure pollutant levels and compare existing levels with the Federal air quality standards. These measurements are made for Air Quality Control Regions (AQCR's), which consist of contiguous counties that are affected by the same air pollution sources. States were required to develop in the early 1970's air quality implementation plans to ensure that Federal standards would be met by 1977. As part of these plans, some of the larger metropolitan areas were required to develop transportation control plans that would reduce total emissions from motor vehicles by restricting their use in congested areas. The impact of alternative freight system plans on air quality would necessarily be considered in more detail in those AQCR's requiring a reduction in emissions.

Examples of relative importance of air pollution generated by freight movements are given in Table F-4. The share attributable to freight transport is small, with the greatest impact occurring for emissions of NO_x where trucks and locomotives combined account for an average of 3 percent of the total emissions. It should be noted that this proportion does not include emissions from gasoline-powered trucks, which account for about 13 percent of the total VMT driven on urban streets. Emissions of CO rates from these vehicles would be higher than from the diesel-powered trucks, but NO_x emissions rates would be lower.

TABLE F-4

1970 LOCOMOTIVE AND DIESEL TRUCK AIR POLLUTANT EMISSIONS FOR FOUR INDIANA AIR QUALITY CONTROL REGIONS

AIR QUALITY CONTROL REGION SOURCE	POLLUTANT EMISSIONS (TONS/YEAR)				
	PARTICULATE	SO_2	CO	HC	NO_x
Chicago					
Diesel trucks	231	424	3,063	612	3,204
Locomotives	182	472	509	363	545
All	380,797	514,818	730,104	112,721	144,829
Louisville					
Diesel trucks	71	127	917	184	959
Locomotives	35	90	98	70	104
All	35,778	131,024	89,543	18,874	30,182
Cincinnati					
Diesel trucks	35	63	452	91	473
Locomotives	6	15	16	12	18
All	59,432	166,450	25,010	5,489	44,566
Indianapolis					
Diesel trucks	551	992	7,155	1,431	7,484
Locomotives	234	606	650	466	701
All	85,347	179,117	741,369	161,322	114,205

Source: *The State of Indiana Air Pollution Control Implementation Plan*, Volume I. Indiana State Air Pollution Control Board (Jan. 1972).
Note: 1 ton = 0.907 metric ton.

Method to Determine Air Pollution Impact

The general process for air pollution impact analysis is to (1) measure ambient levels of pollutants, (2) estimate the additional or incremental pollutants generated likely to occur as a result of the project or plan, and (3) estimate the impact of the pollutants generated on local air quality. Different levels of detail can be used, depending on where existing air quality stands in relation to Federal and state standards and the sophistication of the estimates of fuel consumption. The effect of each of these factors on the three steps is discussed more fully in the following.

Measures of ambient air pollution usually can be obtained from the state agency responsible for developing and supervising the air quality implementation plan. Unfortunately, such emissions data are only useful for general analysis because the information from monitoring stations is available only at a few specific points, or at best gives estimated yearly concentrations for a region (*F-36*). Inputs into the more sophisticated models described later required emissions data at receptor locations adjacent to the facility being proposed. This type of information can only be obtained through site-specific measurements.

Estimate the Amount of Pollutants Generated

Estimates of total pollutants emitted for different freight plans can be made using a direct conversion from fuel consumption to emissions generated. Therefore, the accuracy of the estimate of emissions generated is related directly to the accuracy of the fuel consumption estimate. The best current source for conversion factors is the *EPA Compilation of Air Pollutant Emission Factors* (*F-35*). Conversion factors are given in this report for heavy-duty diesel-powered vehicles, aircraft, locomotives, and ships. The limitations and general accuracy of the data have been rated by EPA from A through E. The meaning of each rating is given as:

> For a process with an "A" ranking, the emission factor should be considered excellent; i.e., based on field measurements of a large number of sources. A process ranked "B" should be considered above average; i.e., based on a limited number of field measurements. A ranking of "C" is considered average; "D" below average; and "E" poor.

Data are available for (a) stationary gas turbines and (b) heavy-duty, general utility, gaseous-fueled engines; both are used to operate pumping stations on some pipelines. The data required to use each of these tables vary and are discussed briefly in the following.

Data Requirements for Heavy-Duty Diesel-Powered Vehicles

Emission factors for heavy-duty diesel engines used in most intercity trucks are given in Table F-5. Diesel-powered trucks generally emit larger quantities of sulfur dioxide and nitrogen oxide than automobiles, but they emit less hydrocarbons and carbon monoxide. The conversion factor given in the table can be applied if either the total fuel consumed is calculated or the total miles traveled is available. The former would be more accurate because variations due to engine size, load carried, topography, and operating conditions would be taken into consideration.

Data Requirements for Locomotives

Railroad locomotives are used in switching and line-haul operations. Emission factors for the five basic types of engines within these two groups are given in Table F-6. Total emissions can be calculated using the fuel consumption values calculated previously or the estimate of horsepower-hours required. For system planning, major emphasis will be on the road engines. The wide variation among the three types of road engines can be accounted for directly if the information is available on the type of power units that would be used. If there is some doubt, the values can be averaged based on the mix of locomotives used by the railroads within a state. Switch engines may have a small impact within a local area if changes in yard size, location, or operations are proposed.

Data Requirements for Other Modes

The emission factor data for inboard-powered vessels have been broken into two categories—steamships and motor ships. The former have steam turbines driven by external-combustion oil-fired engines; motor ships operate using internal-combustion diesel engines. The accuracy of the emission data developed for ships is only rated at "D," so it should be used only for order-of-magnitude calculations. In addition, the type of vessel or tow power required must be specified. Finally, the emission factors are divided into time under way and time in berth, so that these two variables must be known or estimated.

Emission rates are given in the EPA report for different types of aircraft. If the mix of freighter aircraft is known, more accurate emission estimates can be made. It should be noted that input into this process is the number of landings or take-offs from an airport rather than total fuel con-

TABLE F-5

EMISSION FACTORS FOR HEAVY-DUTY, DIESEL-POWERED VEHICLES.[a] EMISSION FACTOR RATING: B

	EMISSION			
POLLUTANT	LB/10^3 GAL	KG/10^3 LITRE	G/MI	G/KM
Particulate	13	1.6	1.2	0.75
Sulfur oxides [b]	27	3.2	2.4	1.5
Carbon monoxide	225	27.0	20.4	12.7
Hydrocarbons	37	4.4	3.4	2.1
Nitrogen oxides [c]	370	44.0	34	21
Aldehydes [d]	3	0.4	0.3	0.2
Organic acids	3	0.4	0.3	0.2

[a] Data based on weighting factors applied to actual tests conducted at various load and idle conditions with an average gross vehicle weight of 30 tons (27.2 MT) and fuel consumption of 5.0 mi/gal (2.2 km/litre).
[b] SO_x as SO_2; data based on fuel with 0.2 percent average sulfur content.
[c] NO_x as NO_2.
[d] (As HCHO).

sumed in operations or miles traveled, as has been the case for other modes.

Emissions factors for stationary gas turbines and heavy-duty, general-utility, gaseous-fueled engines are also given in the EPA report (*F-35*). These represent the type of power units that might be used with pipelines, although electric pumps might be used also. If the pumping units proposed for a pipeline were specified, the values for emission factors given in these tables could be used.

Estimate the Impact of Pollutants Generated

Compare Total Weight Generated

The simplest and most direct way to estimate the air pollution impact of various freight system plans is to apply the emission factors and compare the total weight of pollutants produced by different plans. This "burden" type of assessment can be done on a statewide basis, a regional basis (AQCR's), or along a corridor. These types of estimates have been made for analysis of the Conrail system plan done by Battelle (*F-6*) and for branch lines in Wisconsin (*F-1*) and Pennsylvania (*F-25*). To determine if more detailed modeling is required, the magnitude of the differences and the significance of the impact can then be compared with the base values. The existence of transportation control plans within an AQCR is a general indication of the severity of present pollution levels and the potential need for detailed assessment should the results from the burden analyses indicate a potential increase in emissions.

Compare Concentration Generated

In areas where a more detailed analysis is required to determine actual air pollution damage, it will be necessary to actually estimate the concentration of pollutants using the following process:

1. Locate receptors that might be impacted.
2. Develop methods to estimate concentration of the pollutants at the receptors using existing or new dispersion models.
3. Estimate the pollutants generated by the alternative system being tested using the conversion process cited previously.
4. Determine the other input variables required for the dispersion model, including meteorological data and existing concentrations.
5. Determine the length of time receptors are exposed to levels of pollutant concentration and assess the impact of these concentrations relative to the Federal standards.

Steps 2, 4, and 5 in this process are the most difficult because they have to be done at a very fine level of detail using sophisticated modeling techniques. In fact, no pollution dispersion models have been developed for locomotives or shipping vessels. However, models for dispersion for highways are described in work by the FHWA (*F-37*) and the EPA (*F-38*). In addition, work has been done on dispersion around airports for the FAA (*F-33*) and the EPA (*F-31*). Any of these models could be applied to analyze the detailed impacts of the air pollution generated by freight movements. There are several reasons why this level of detail will probably not be required. First, freight movements generate only a small proportion of total pollutants in an area. Second, trucks and planes carrying freight represent a small proportion of the total vehicle mix. Third, except for airplanes (where concentrations exist around airports) the major freight movements of interest to statewide planners are between rather than within urban areas.

If, after careful consideration of these factors, an agency still feels that detailed modeling of air pollution is required, the analysis should be a coordinated activity between the state agency responsible for air quality control and the state DOT. The total air quality of a region could be modeled and then the amount resulting from freight movement could be separated from the amount generated by other sources.

NOISE POLLUTION

The impact of a freight system plan on noise levels must be considered in a different context from the impacts discussed previously because of the localized and noncumulative character of noise. Adverse effects of noise, if any, generally occur within about 1,000 ft (305 m) of a highway and within 3,000 ft (914 m) of a railroad. Noise impact distances for airports vary due to the particular characteristics of the landing and take-off cycle. The critical element is the location of persons with respect to the noise and their perceptions of the change in noise level.

Concern about increasing noise levels led to the Noise Control Act of 1972, which established a national policy designed "to promote an environment for all Americans free from noise that would jeopardize their public health and welfare." Although the act placed primary control for source regulation (i.e., vehicles) on the Federal government, states and other political subdivisions have the right to control the use of noise sources and set permissible noise standards (*F-45*).

Noise Criteria from HUD Guidelines

Type of Method. The simplest procedure for determining the impact of increased noise levels is to use the curves derived by Schultz (*F-44*) shown in the HUD booklet, *Noise Assessment Guidelines* (*F-48*). By using the curves, the more complex modeling process described later can be avoided. The curves relate the number of vehicles or aircraft (in the vicinity of an airport) to the distance from the source. The distance can be modified using factors to account for various shielding effects. Noise levels at different distances are rated on the graphs as clearly acceptable, normally acceptable, normally unacceptable, and clearly unacceptable. Rail noise is rated using the same criteria, but no allowance is made for the number of trains per day.

Data Requirements. Heavy truck daily volumes or the number of day and night landings and take-offs from each runway of an airport are required for use of the curves. Noise from railroads is predicted by use of a table that relates the HUD acceptability criteria to distance from the right-of-way. The populations at different distances from a road, track, or airport runway are also required to determine relative impacts.

TABLE F-6

EMISSION FACTORS BY LOCOMOTIVE ENGINE CATEGORY.
EMISSION FACTOR RATING: B

POLLUTANT	ENGINE CATEGORY				
	2-STROKE SUPER-CHARGED SWITCH	4-STROKE SWITCH	2-STROKE SUPER-CHARGED ROAD	2-STROKE TURBO-CHARGED ROAD	4-STROKE ROAD
Carbon monoxide:					
lb/10^3 gal	84	380	66	160	180
kg/10^3 litre	10	46	7.9	19	22
g/hp-hr	3.9	13	1.8	4.0	4.1
g/metric hp-hr	3.9	13	1.8	4.0	4.1
Hydrocarbon:					
lb/10^3 gal	190	146	148	28	99
lb/10^3 litre	23	17	18	3.4	12
g/hp-hr	8.9	5.0	4.0	0.70	2.2
g/metric hp-hr	8.9	5.0	4.0	0.70	2.2
Nitrogen oxides:[a]					
lb/10^3 gal	250	490	350	330	470
kg/10^3 litre	30	59	42	40	56
g/hp-hr	11	17	9.4	8.2	10
g/metric hp-hr	11	17	9.4	8.2	10

Source: "Compilation of Air Pollution Emission Factors," Office of Air Quality Planning and Standards, U.S. EPA, Research Triangle Park, N.C. (July 1974).
[a] NO_x as NO_2.

Evaluation of Method. The main advantage of the HUD criteria is that they can be used without any complex calculations or references to the various types of physical noise measurement. The results, although not precise, do provide a clear indicator of the impact of various plans. The methods provided reflect the public awareness of truck and airport noise, whereas noise from trains is not treated in as much detail. Therefore, the curves provided to calculate truck noise are more useful than the table provided for rail noise because the results vary with the daily truck volume. The number of trains per day, a significant variable in freight system planning, is not considered.

Noise Modeling

Noise is a physical phenomenon that has three measurable characteristics—volume (sound pressure), frequency (pitch), and variability. To model the volume of sound, units of decibels (dB) are used. To account for the variation in human response to different frequency of sounds a weighting scale (A scale) has been developed. For this scale, high frequencies are weighted more heavily than low ones to simulate human response.

Experiments have revealed that this scale is useful for simulating human response to rail and traffic noise. A 1-dBA change in sound levels cannot be detected by most people, a 3-dBA change is easily noticed, and a 10-dBA change is judged to be a doubling (or halving) of noise volumes.

Variability in sound levels refers to periodic fluctuations that occur due to changing traffic volumes or isolated occurrences (e.g., the passing of a freight train). This variability is generally accounted for by using one of the following four measures:

- Equivalent sound level (L_{eq}): Represents a constant sound level, which, for given condition and duration, will have the equivalent sound energy as a time-varying sound. To account for increased nighttime sensitivity to sound, a modified version of the L_{eq}, the day-night equivalent sound level (L_{dn}), has been developed. The L_{dn} weights nighttime noises (10:00 pm-7:00 am) by an additional 10 decibels.
- Statistical noise level (L_n): Used in the analysis of highway noise to represent the percent of time a given noise level is exceeded. FHWA and state DOTs generally use L_{10} noise levels in determining impact.
- Single-event noise equivalent level (SENEL): Measures the subjective response to isolated events, such as trains passing.
- Aircraft sound description system (ASDS) and noise exposure forecasts (NEF/L_{dn}): Two complex measures developed by the FAA, the EPA, and HUD to quantify aircraft noise.

The noise impact of a specific project can be calculated using the following three-step process:

1. Measure or estimate existing noise levels and quantify the impact for different land uses.

2. Identify criteria for acceptable noise levels. National criteria are available from HUD (*F-49*), EPA (*F-45*), and FHWA (*F-46*). State and local laws and agencies should also be screened to determine if any state or local regulations have been issued.

3. Estimate new noise levels for each alternative freight transportation plan and compare the noise levels with the criteria.

The techniques available to estimate the noise impact for each of the alternative modes are discussed in the following.

Highway Noise

Type of Method and Application. As explained previously, in this report "motor vehicles" refers to trucks only. However, when noise analysis is considered, the combined impacts of trucks and cars in a traffic stream are included. Therefore, although individual trucks are noiser than individual cars, the percentage of truck traffic in a vehicle stream must be considered.

Procedures developed for modeling highway traffic noise by Bolt Beranek and Newman (*F-41, F-42*) use a series of graphs to calculate L_{10} and L_{50} levels of noise at different distances from a highway (noise contours). Computer programs are available in many state DOTs to compute these noise contours. Therefore, no further discussion of the method is included here.

Data Requirements. The level of detail used in the analysis depends on the input data available. At the first level, only vehicle volume, average speed, and truck-to-auto ratio are required. If more detail is available, data on (1) existing noise levels; (2) highway elevation, depression, and shielding; (3) traffic patterns (stop-and-go versus continuous); (4) physical features (grade, lane width, and number of lanes); and (5) type of pavement surface would also be required.

Evaluation of Method. The methods used to estimate the impact of highway noise are readily available and are constantly being refined (*F-42*). However, the detailed input data required to use these existing methods may not be aavilable for all elements in a statewide freight system plan. A more logical modeling approach would set up general criteria to isolate corridors where the change in truck volumes would create the greatest change in noise levels. Then the modeling process could be conducted in these corridors. Small changes in truck volumes do not have a significant impact on noise levels, as noted in the Wisconsin (*F-24*) and Pennsylvania (*F-25*) rail studies.

Railroad Noise

Type of Methods and Applications. Rail mainline, branch-line, and yard operations all contribute significantly to the level of noise in the surrounding area. Noise from moving freight trains is generated by engine exhaust, casing, intake, and fan noise and by general rail/wheel noise of both the engine and the freight cars (*F-43*). The amount of noise generated will vary, depending on the condition of the track and the rolling stock. No method has been developed that considers each of these variables; if one were available, the level of input data required would probably obviate its use.

Techniques that model some of these variables have been developed by Swing (*F-39*), Swing and Pies (*F-50*), and Hanson and Wittig (*F-40*). The least complex method, proposed by Swing (*F-39*), uses the following three-step process to estimate railroad noise levels:

1. Calculate the equivalent number of train operations by

$$N = N_d + 10\,N_n \qquad \text{(F-6)}$$

where N_d is the number of daytime operations (between 0700 and 2200) and N_n is the number of nighttime operations (between 2200 and 0700).

2. By use of a nomograph, calculate the noise level at the distance desired.

3. Make adjustments for track type and condition, grade, curves, bridge work, and use of helper engines.

A detailed description of the theoretical basis for this work is contained in the report by Swing and Pies (*F-50*).

A more complex method, developed by BCL (*F-21*), uses a computer program to plot the day-night equivalent sound level, L_{dn}, as a function of distance and the number of trains per day. The analysis uses the single-event noise level (SENEL) calculated for each train, with night operations weighted more heavily than daytime operation. Separate calculations of SENEL are made for the locomotive and the cars. These are then added together using logarithms to obtain the total noise level produced. An attenuation factor was developed using the information from Wittig (*F-51*) to account for the relationship between the length of the source (i.e., the train) and the distance to the observer.

Noise from proposed yards may also have an impact if they are located in developed areas. Information compiled by the EPA (*F-47*) has been used by BCL (*F-21*) to analyze the impact of yard noise due to increased rail traffic. According to the report, the relative impact of a yard is dependent on "the population density within a radius of 2,000 feet of the noise center of the yard. Beyond this distance, the noise contribution of the yard operations is of the same order of magnitude as the level of noise that is considered acceptable" (*F-21*).

Data Requirements. All of the models developed require information on the location of population with respect to the rail line. In addition, the simple method proposed by Swing uses the number of daytime and nighttime operations, track type and condition, grade, curves, bridge work, and use of helper engines. The method developed by BCL uses the same variables plus the train speed and length of the train. Inputs into the analysis of yard noise include the

new and the old volume of traffic stated in cars switched during the day and at night.

Evaluation of Methods. Methods for evaluating rail noise are not as widely used as those for highway and aircraft noise. The methods described are straightforward and can be easily applied if the input data are available. The simple method developed by Swing has the advantage that no computer processing is required. However, the adjustment factors for various track conditions require detailed track chart information. Similar problems with data requirements exist for the BCL process.

Aircraft Noise

Noise around airports is a very serious environmental problem that has received a good deal of study and publicity. There is, however, an inherent difficulty in dealing with aircraft noise in a study of impacts related to freight movements. As noted previously, most air freight is carried in the excess space on passenger aircraft and there is no accepted way to attribute a portion of the noise generated to freight movement.

Type of Methods and Applications. Computer models to simulate aircraft noise have been developed by the FAA (*F-52*) using the aircraft sound description system (ASDS) and by HUD and EPA (*F-53, F-54, F-55*) using noise exposure forecasts (NEF) modified to include differences in annoyance levels between day and night operations (L_{dn}). By using the models, contour lines can be drawn around airports to indicate areas where noise levels are unacceptable. Both of the models consider variation in aircraft operations and runway design in detail.

Data Requirements. Each of the techniques requires (1) the number of operations by type of aircraft by time of day; (2) aircraft flight plans, including glide slope angle; (3) landing and take-off flight paths; (4) wind conditions and runway orientation; (5) noise barriers and abatement measures; and (6) preferential runway rules.

Evaluation of Methods. The models available to predict aircraft noise have been tested and are probably already available in states with large airports. If freight system plans result in a dramatic increase in freight-related air traffic, these models can be applied. Particular attention should be focused on the increased nighttime operations of freighter aircraft. (Air freight is generally hauled in the off-peak periods of air operations.)

WATER POLLUTION

Variation in local water pollution impacts can occur from different freight transportation plans. These impacts are of three main types—those occurring due to (1) regular operations, (2) accidents and emergencies, and (3) construction activities. Impacts from regular operations include runoff of (a) defoliants used for vegetation control and (b) de-icing compounds. Emergencies and accidents, such as oil and chemical spills, often have a more dramatic and obvious local impact. Finally, construction activities contribute to stream-silting and radical modification of surface-water flows.

Long-term impacts from construction include destruction of coastal and inland wetlands, diversion of stream flows, and changes in the rate of absorption. In cases where a facility is being constructed or expanded as part of a freight system plan, these critical bodies of water and wetlands should be studied in greater detail.

Highway Movements

Many of the water pollution impacts associated with highways are not directly attributable to truck movements. In most cases the highways would exist to carry passenger vehicle traffic even if there were no trucks. These general impacts include those caused by herbicides and defoliants, those caused by highway salting, and those caused by changes in surface- and ground-water supplies due to the existence of impermeable pavement surfaces. Water pollution from spills of hazardous substances caused by truck accidents should be considered. Conversion factors based on national averages are available and can be used to predict the number of accidents that will occur for trucks carrying this type of load (*F-56*). Data requirements for this process include the number of truck shipments made of different hazardous materials. By using this information and standard hydrological techniques (*F-61*), estimates of possible water pollution could be made.

Rail Operations

Water pollution from regular railroad operations results from (1) use of herbicides and defoliants, (2) spilling of fuel during refueling, (3) dumping of crankcase oil and dirty wastewater from washing operations, (4) dumping of contaminated radiator water, and (5) dumping of sanitary waste. The following factors lead to the conclusion that these sources of water pollution need not be considered in analysis of system plans:

- All of the sources listed can be controlled by practicing progressive railroad operating techniques.
- The impacts, because they are generally localized and represent a small part of the water pollution problem, need not be considered in system planning.
- The impacts are not directly correlated with the amount of freight moved, but are more dependent on the operating practice of the railroad.

The problem of accidental spills from rail traffic can be dealt with by use of the process cited previously for trucks. Over-all probabilities are available (*F-56*) and methods of control are explained (*F-57*).

Pipelines and Vessels

The impact of vessel and pipeline movements on water quality has been limited primarily to oil transport. A comprehensive analysis of this impact is contained in Volumes 4 and 5 of the Final Environmental Impact Statement issued for the Trans-Alaska Pipeline (*F-59, F-60*). This report concludes that the impact of the pipeline operation itself on water pollution will be slight. A detailed analysis is given of the amount of oil discharged into oceans and ports by increased tanker movements. References from

the U.S. Coast Guard Pollution Incident Reporting System are used to develop accident probabilities. In addition, calculations are made of the oil emitted from regular operations, including tank cleaning (which accounts for 70 percent of the oil released by tankers), ballast discharges, and terminal leakage and spills.

Data Requirements, Summary and Conclusions

This section starts with a review of the various procedures and data requirements presented earlier in this appendix on impact estimation. It then identifies the capabilities being sought in estimating impacts for freight statewide transportaion systems planning. Next, three different program levels are introduced ranging from a broad policy or overview scale to a sophisticated capability for determining impacts on a systems or corridor basis. Finally, the data needed to support each of the program levels are identified.

REVIEW OF PROCEDURES AND DATA REQUIREMENTS

The procedures developed to date to measure energy consumption, vehicle emissions, noise levels, and water quality are generally of two types. First, there have been some generalized measures related only to the unit consumption of energy or production of pollutants. The estimates of energy intensiveness (Table F-2) and emission factors (Tables F-5 and F-6) are examples of data useful primarily in making broad comparisons between modes. The use of these measures is straightforward; the factor is simply multiplied by some production measure such as net ton-miles (m ton-km), hours operated, or gallons (litres) of fuel consumed.

Most of the procedures developed to date are route-specific; that is, they were developed for application at the project rather than the systems level.

Some procedures are physically based, others are largely empirical and simply represent the application of unit consumption or production measures to a more defined situation. In either case, the refinement comes largely from incorporating additional vehicle, roadbed, and load factors (Table F-1) into the computations. The procedures available today do not provide uniform coverage of the different modes and impacts. Much work remains to be done to fill in the voids. However, it must be remembered that the procedures presented in this appendix were not developed for state-level freight planning purposes, but rather as part of a larger program to estimate aggregate transportation-related energy consumption, emissions, and noise effects.

With the exception of the Battelle work and to some extent in the use of rail performance calculators, most of the procedures discussed have not been applied in a systems context. Provided one is willing to spend the time and effort involved, the computations can be extended to the system level to the extent that supporting traffic, operating, and physical data are available, as well as information on ambient conditions necessary to determine air, noise, and water pollution impacts. Most procedures are of recent origin and have been tested only on a limited basis. The exceptions are the methodologies developed by FHWA and others for estimating emissions and the noise impacts from highways and airports, including passenger transport as well as freight movements.

Appreciable research work is presently under way to provide better information and procedures for impact estimation, especially in the field of energy consumption. This will undoubtedly lead to revised and extended unit values more closely related to the operating and physical environment. The planner should be alert to such developments and upgrade present information and impact computation procedures as this new material becomes available.

Desired Capabilities

The specific impact estimating capabilities sought by states (for freight statewide systems level planning) include, among others:

- Preparing estimates of total energy consumption or emission production for the state as a whole, subareas, or corridors for the different freight modes.
- Identifying those freight services which are energy-intensive and those which are energy-efficient.
- Comparing freight energy consumption and emissions production with that of passenger transport or between freight modes.
- Identifying those freight-related emissions having a potential adverse effect on public health and safety at a local level.
- Measuring the impact of state government proposed regulatory controls and infrastructure investments on energy consumption and emissions production by the private sector.
- Simulating energy consumption and emissions production effects of transport facilities located within the state.

These desired capabilities are structured into several different program levels in the following. Realization of one or more of these capabilities requires public expenditure for staff and the carrying out of supporting technical studies. Some capabilities may already exist, some will be realized easier than others, and some may not be achieved for many years.

Program Levels

By use of the definitions established earlier in this report (Table F-6), three different program levels are described as follows:

Stage I. Under this program level, the main emphasis is on preparing aggregate order-of-magnitude estimates of energy consumption or emission production (air pollution only). The purpose is to (1) prepare reasonably good estimates on a statewide or corridor basis, (2) become familiar with where and how freight transport affects energy consumption and emission production, and (3) recognize the efficiencies of different modes and services. Under Stage I, estimates would be prepared through simple transformations of commodity flows, hours operated, or fuel consumption data using emission and fuel consumption factors. It would seek to cover all freight modes. No attempt would be made to reflect operational differences (other than route distance) or physical characteristics.

It should be noted that many state DOTs have already gone beyond this stage in preparing estimates of highway- and aircraft-generated air pollution impacts.

Stage II. Under this program level, the capabilities achieved in Stage I are extended to include (1) identifying services that are energy intensive, (2) making intermodal comparisons, and (3) identifying emissions having a potential adverse effect.

During Stage II, estimates of noise pollution impacts should be made, along with more detailed energy and air pollution analyses. The basic method is still a data transformation similar to that used in Stage I but with greater detail on the operating and physical characteristics of the system or corridor (route). These would include vehicle and power plant characteristics, operation data, ambient conditions, and population. If a severe problem exists, more detailed estimates (using data specified in Stage III) may be required if there is a significant difference in total pollutants generated by different plans. Rough estimates of noise impacts can be made using the data specified and the curves developed by HUD. Most state DOTs already have available sophisticated noise modeling techniques that have been applied to recent highway and airport projects, but lack information on other modes. By applying the simplified technique, a uniform analysis is possible for alternative corridor plans. Most states should be able to develop the data specified in Stage II because it represents only a small addition to Stage I data. By obtaining these data, a general understanding of the impact of a freight transport system can be obtained prior to the development of the more sophisticated modeling procedures described in Stage III.

States might also under Stage II investigate and become familiar with the capabilities of performance calculators used by railroads located within their borders.

Stage III. Under this program level, the capabilities achieved in Stages I and II would be further extended to develop the ability to simulate freight system energy consumption and emissions production impacts on a statewide or corridor (route) basis covering all modes. The purpose of this would be to measure the effects of regulatory, service, or infrastructure changes. Development of such a capability would normally be coincident with other phases of the freight planning process.

Data necessary to develop these models vary among states. Data already exist in some states to describe the geometric characteristics of the highway system and track charts are available to describe similar characteristics for most rail lines. Physical data for waterways and pipelines are more limited at the state level. The ideal simulation process for highways would use the computerized information describing highway routes to prepare programs analogous to train performance calculators. These highway simulation models could then be used to calculate the energy impact of changes in truck vehicle flows. If models were incorporated with existing air and noise pollution models, a complete package could be developed to calculate highway impacts of alternative freight transport plans on a segment, corridor, or statewide level. Similar unified models could be developed for rail analysis by combining the existing train performance calculators with the noise impact analysis methods described in this appendix. At present no detailed estimates of air pollution resulting from rail operations can be made because of lack of research in this area.

Ideally, similar simulation capability should be developed for waterborne, air, and pipeline movements to replace order-of-magnitude estimates prepared under Stage I. This, however, is of lower priority than developing rail capability. Also a factor is the presence of such facilities within a state and the desire to undertake such work. It might be desirable for several states to combine their efforts to develop a multistate simulation capability more in keeping with the average shipment lengths made by these other modes.

Development of a simulation capability should be viewed as an on-going evolutionary process whereby new calculation routines and unit values are incorporated into the computer programs as improved techniques and information become available.

Data Required for Impact Estimation

Data required for Stages I, II and III are given in Tables F-7, F-8, and F-9, respectively.

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TABLE F-7

DATA REQUIREMENTS FOR STAGE I TRANSPORT SYSTEM PLANNING

IMPACT	QUANTITY ESTIMATE	DATA REQUIREMENTS																	
		IMPACT RELATED	Rail	Truck	Waterborne	Pipeline	Air	SYSTEM USE	Rail	Truck	Waterborne	Pipeline	Air	SITE SPECIFIC	Rail	Truck	Waterborne	Pipeline	Air
Energy Consumption	BTU (joules) Required Gallons (litres) Consumed	Fuel Consumed Per Net Ton-Mile (metric ton-kilometre) BTU (joules) Per Gallon (litre)	X X	X X	X X	X X	X X	Net Ton-Miles (metric ton-kilometres) Shipped	X	X	X	X	X	None					
Air Pollution	Weight of Carbon Monoxide (CO), HydroCarbons (HC), & Nitrogen Oxides (NO_x) Emitted	Pounds (kgs.) of CO, HC, & NO_x emitted per 1000 gallons (litres) Pounds (kgs.) of Emissions per LTO Cycle	X -	X -	X -	O O	- X	Gallons (litres) of Fuels Used	X	X	X	O	-	Number of Landing & Takeoff (LTO) operations	-	-	-	-	X

Key: X Data Item Required for Modal Impact Analysis
O Minor Impact from Mode
- Data Item Not Required for Modal Impact Analysis

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TABLE F-8

DATA REQUIREMENTS FOR STAGE II TRANSPORT SYSTEM PLANNING

IMPACT	QUANTITY ESTIMATE	DATA REQUIREMENTS																	
		IMPACT RELATED	Rail	Truck	Waterborne	Pipeline	Air	SYSTEM USE	Rail	Truck	Waterborne	Pipeline	Air	SITE SPECIFIC	Rail	Truck	Waterborne	Pipeline	Air
Energy Consumption	BTU (joules) Required Gallons (litres) Consumed	Gallons (litres) of Fuel Consumed per Horsepower-hour (kw-hr)	X	X	X	X	X	Net Ton-Miles (metric ton-kms.) Shipped of each Commodity Net Tons (metric tons) Carried for each Vehicle for each Commodity	X	X	X	X	X	None					
		BTU (joules)per Gallon (litre) for Different Fuels	X	X	X	X	X		X	X	X	X	X						
								Average Train Size & Consist	X	-	-	-	-						
								Number & Type of Power Unit Used	X	X	X	X	X						
								Average Empty Vehicle Weight	X	X	X	-	X						
								Average Operating Speed	X	X	X	X	X						
Air Pollution	Weight of CO, HC, & NO_x Emitted Compared to Ambient Conditions	Pounds (kgs) of CO,HC, & NO_x Emitted per 1000 Gallons (litres) for Different Power Units	X	X	X	O	X	Gallons (litres) of Fuel Consumed by Corridor & Segment	X	X	X	O	X	None					
		Existing Pollution Levels in AQCR	X	X	X	O	X												
Noise Pollution	Number of Person Affected by Increased Noise Levels	HUD Acceptability Criteria	X	X	O	O	X	Number of Vehicles per Day	-	X	O	O	x	Population Distribution near Segment or Around Airport	X	X	O	O	X

Key: X Data Item Required for Modal Impact Analysis
O Minor Impact from Mode
- Data Item Not Required for Modal Impact Analysis

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TABLE F-9

DATA REQUIREMENTS FOR STAGE III TRANSPORT SYSTEM PLANNING

IMPACT	QUANTITY ESTIMATE	DATA REQUIREMENTS																				
		IMPACT RELATED	Rail	Truck	Waterborne	Pipeline	Air	SYSTEM USE	Rail	Truck	Waterborne	Pipeline	Air	SITE SPECIFIC	Rail	Truck	Waterborne	Pipeline	Air
Energy Consumption	BTU (joules) Required Gallons (litres) Consumed	Resistance Equations	X	X	X	X	X	Net Ton-miles (metric ton-kms)) Shipped of Each Commodity	X	X	X	X	X	Power Unit Used on Each Route	X	X	X	X	X
		Train Performance Calculations	X	-	-	-	-	Net Tons (metric tons) Carried per Vehicle for each Commodity	X	X	X	X	X	Train (lounge) Size & Consist on Each Route	X	-	X	-	-
		Gallons (litres) of Fuel Consumed per Horsepower-Hour (kw-hr) for Different Power Units	X	X	X	X	X	Proportion of Freight Carried in Passenger Aircraft	-	-	-	-	X	Hull Condition of Vessel	-	-	X	-	-
								Empty Weight of Vehicles	X	X	X	-	X	Pipeline Diameter	-	-	-	X	-
														Fluid Characteristics	-	-	-	X	-
														Speed Profile by Route	X	X	X	X	X
														Elevation Changes & Curves Along Each Route	X	X	X	X	X
														Speed/River Current	-	-	X	-	-
Air Pollution	Ambient & Concentration of CO, HC, & NO_X emitted	Emission Rate of CO, HC, & NO For Different Power Units	X	X	X	X	X	Gallons (litres) of Fuel Used by Corridor & Segment	X	X	X	X	-	Ambient Air Quality	X	X	X	X	X
	Number of Persons Affected by Increased Pollution Levels	Dispersion Models for CO, HC, & NO_X from Different Sources	X	X	X	X	X	Number of LTO Operations	-	-	-	-	X	Meteorological Data (Unit Speed & Direction)	X	X	X	X	X
														Population Distribution Near Segment or Around Airport	X	X	X	X	X
														Number & Type of Power Unit Used	X	X	X	X	X
Noise Pollution	Number of Persons Affected by Increased Noise Levels	Noise Dispersion Models	X	X	X	X	X	Average Train Length	X	-	-	-	-	Population Distribution Near Segment or Airport by Type of Activity (Work, School, etc.)	X	X	X	X	X
								Number of Vehicles per Hour by Time of Day	X	X	X	-	X	Speed Profile (including stop & starts)	X	X	X	-	-
														Elevation Changes & Curves Along Route	X	X	-	-	-
														Shielding Along Route	X	X	-	-	X
Water Pollution	Amount of Pollutants spilled into Bodies of Water	Accident Rates of Moving Vehicles	X	X	X	X	O	Net Ton-Miles (metric ton-kms) of Polluting Commodities	X	X	X	X	O	Location of Streams, Lakes & Wetlands	X	X	X	X	O
								Vehicles Per Day	X	X	X	-	O	Location of Terminal Facilities	-	-	X	X	O

Key: X Data Item Required for Modal Impact Analysis
O Minor Impact from Mode
- Data Item Not Required for Modal Impact Analysis

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APPENDIX G

UNMET DATA NEEDS AND STRATEGIES FOR RESOLVING DEFICIENCIES

The purpose of this appendix is (a) to determine unmet data needs and (b) to propose and evaluate strategies for resolving these unmet needs. To do this, it builds on the data supply and data requirements developed in earlier appendixes. Detailed information on available secondary data sources is presented in the User's Manual (*G-13*). Freight data requirements based on an issues or problems approach were developed in Appendix A. Freight data requirements stemming from a detailed examination of quantitative planning techniques for demand estimation, modal choice analysis, network analysis, economic evaluation, and impact estimation were discussed in Appendixes B, C, D, E, and F, respectively. The data supply of the manual is systematically compared against the data requirements of Appendixes B, C, D, E, and F to derive unmet data needs.

Once unmet data needs have been identified, strategies for resolving these needs can be proposed. This is done in the latter half of this appendix for major unmet data needs.

UNMET DATA NEEDS

For each of the 31 data categories given in Figure 1, assessments were made of data availability and quality. The results are given in Table G-1. An over-all assessment was made only after considering the present state of affairs in the following four subcategories:

- *Form.* Entries refer to the typical format of available secondary data and the associated units of measure, where applicable.
- *Availability.* Entries describe the general availability of the data for state use, including (1) anticipated difficulties in obtaining access to the data, (2) the need to seek the

TABLE G-1

ASSESSMENT OF DATA DEFICIENCIES

Category	Assessments
Commodity Production Commodity Consumption	Form. Statistics generally in terms of numbers, weight, or cubic volume produced or consumed per unit area. Source data often at the county level for major products, state level for minor products. Summary data generally available at the state level. Availability. Commodity production statistics are generally available for all major agricultural, extractive, and manufacturing sector products through governmental agencies or through trade associations. Commodity consumption statistics are available only for a limited number of major products. Multiple sources must be contacted. Some data available at state level, and some only available at Federal level. Release of data may be limited for disclosure reasons. In short, data are available although considerable effort may be necessary to obtain it, particularly in a more disaggregated form. Characteristics. Figures generally report amount produced or consumed, which differs from the amount actually transported. Critical characteristic is the areal dimension for statewide planning purposes, data should be aggregated no higher than county or region. Reliability and quality of the data varies with type, source, etc. Deficiencies. Varies. Deficiencies tend to be (1) availability, (2) level of aggregation, and (3) quality. National data often more available than state level. Distributive techniques can be used to estimate state/region/county production and consumption if data are not available in disaggregated form. Data generally exist somewhere -- may require extensive state DOT staff probing for their locations. Overall, deficiencies judged to be minor.
Commodity Flow Data	Form. Ideally expressed as total annual tons (metric tons) of commodity K moving from zone i to zone j. Zones should be counties or regions within a state for internal traffic; states or multi-state areas for originations or terminations external to the state. Mode independent. Two-digit STCC commodity groupings or more homogeneous equivalent desired. Availability. Commodity flow data are not available in complete form from any source. Some partial data sets exist (e.g., the Census of Transportation for manufactured products, Bureau of Mines data for the more important minerals such as coal, oil, etc.). Such data that do exist are available only at the Federal level. Release of data limited by disclosure requirements. Census data are readily available; Bureau of Mines data have only occasionally been requested by agencies or organizations outside the Federal government. Characteristics. Even among the partial data sets that do exist, data are too aggregated for statewide planning purposes. Critical characteristic is the areal dimension; data should be aggregated no higher than county or region within the state. Commodity detail is generally not needed beyond 2-digit STCC, except for commodities such as coal, iron ore, oil, etc. Most commodity flow data has STCC coding.

Category	Assessments
	Deficiencies. A general lack of data on commodity flow. For the data that exist, the level of aggregation and age limits its usefulness. Not possible for states to assemble their own commodity flow data. Data important to long-term understanding of intercity freight flows and to the development of demand forecasting and distribution models. Overall, deficiencies judged to be major. Deficiencies will increase as states develop capabilities to do more sophisticated freight systems planning.
Traffic Flow Data	Form. Ideally expressed as total annual tons (metric tons) of commodity K moving from zone i to zone j via mode m. Zones should be counties or regions within a state for internal traffic; states or multi-state areas for traffic originations or terminations external to the state. Two-digit STCC commodity groupings or more homogeneous equivalent desired. Availability. Varies considerably by mode. Adequate sample data exist for rail (FRA/ICC one percent waybill sample), census data for waterborne (USACOE records) and air cargo (CAB has segment loadings plus a one-time O/T study). Very limited data available for motor carriers or pipelines. Census of Transportation covers all modes but only for shipments of manufactured products. Characteristics. Data must be aggregated to meet disclosure requirements; becomes too aggregated for statewide planning purposes. Critical characteristic is the areal dimension; data should be aggregated no higher than county or region within the state to be fully useful for statewide systems planning. Commodity detail generally not required beyond 2-digit STCC or equivalent level except for certain bulk commodities such as coal, iron ore, oil, etc. Coding systems among modes are not compatible, definitions differ, various exceptions occur. Deficiencies. Lack of data on motor carriers, stemming from industry refusal to permit governmental access to waybill records for sampling purposes. Disclosure laws generally necessitate a level of aggregation far higher than the county/region level sought for planning purposes. Age of data in some instances. Not possible for states to assemble their own traffic flow data. Data important to long-term understanding of intercity freight flows and to the development of demand forecasting, distribution, and modal choice models. Overall, deficiencies judged to be major. Deficiencies will increase as states develop capabilities to do more sophisticated freight systems planning.
Vehicle Flow	Form. Depending upon mode, either in density form or in records of individual vehicle movements over a particular section of track, highway or waterway for a specified period of time. Availability. Varies by mode. Density data can generally be obtained from individual railroads; form, quality and timeliness varies; data may not cover light-density lines. Train movement data can be obtained directly from railroads. Data on individual carload movements exist at the AAR and individual railroads; however, data rarely released to governmental agencies. Density data for trucks is collected in some states through vehicle classification count programs. Data on individual truck movements exist in motor carrier records, but with the large number of for-hire and exempt carriers, such records are simply too

TABLE G-1 (Continued)

Category	Assessments
	difficult to sample. Roadside survey techniques often used to obtain information on vehicle flow, but labor intensive and costly. Density and vessel movement data do exist for coastal and inland waterway movements; such data are available in aggregated form from the Corps of Engineers. Data on passenger and all-cargo plane movements are similarly available. Characteristics. Varies by mode. Density data may be in weight or number of vehicles passing over a particular section of track, highway or waterway. For rail, density is in gross tons (metric tons) per year (includes weight of locomotive, cars, and caboose). Motor carrier densities are in number of vehicles of a particular wheel/axle configuration per day of count or average day. Waterway densities are in number of vessels in different displacement or draft ranges. No density measure exists for air freight on account of the use of both passenger and all-cargo aircraft for such services. Deficiencies. In the case of density data, the main gap is for truck movements. This, however, can be solved through state efforts. The quality of common carrier density data varies as does the age and availability to governmental agencies. Data important to network analysis. Overall, deficiencies judged to be minor.
Import/Export	Form. Customs records of individual shipments to and from the U.S. which have been sampled to determine domestic originations and terminations. Availability. No problem. Characteristics. Data must be aggregated to state level to meet disclosure requirements. Data do not include all STCC categories of potential interest, especially bulk shipments. Deficiencies. Lack of completeness, which is being rectified in future work. Disclosure laws necessitate a higher level of aggregation than the county/region sought for planning purposes. Being sample data, high variability may exist when data are utilized for planning purposes. Overall, deficiencies judged to be minor.
Routings	Form. Varies. A number of guides exist giving route structure and normal routing practices for for-hire carriers. Routings of motor carriers and airlines prescribed by operating authority. Routings of other modes prescribed by physical plant. None of the above indicated how traffic is actually routed. None indicate traffic using different routings. Routing data shown on waybills. Routing data shown on internal records maintained by carriers for shipment tracing purposes. Availability. Difficult at best. Internal records rarely made available to government agencies on a census or sampling basis, for proprietary reasons. Hindsight sampling possible but difficult to do on a large enough scale to obtain data on shipments or carloads/truckloads via different routings. Varies by mode. Data can only be obtained from carriers; must be maintained by them for claim purposes for a two to three-year period following shipment.

Category	Assessments
	Characteristics. Waybills and internal records generally show arrival and departure times from key intermediate points (e.g. yards or terminals), train number, car number, etc.
	Deficiencies. Combination of a lack of information identifying actual (1) routings and (2) quantity of freight using those routings. Even were carriers willing to share data, difficult to assemble from the multiple sources involved. Various proxy techniques have been developed to estimate carrier shares and routings from other data sources, data important to economic evaluation and network analysis. Overall, deficiencies judged to be moderate, but surmountable.
Carrier Financial Data, Operating Statistics, and Physical Characteristics	Form. Annual, quarterly and monthly reports filed by common carriers with Federal and state regulatory agencies. Special purpose supplemental studies often undertaken by Federal regulatory agencies. Form varies by mode. Covers common carriers only.
	Availability. Data available for public inspection. Appreciable summary material published by regulatory agencies and by trade associations.
	Characteristics. Generally in the form of carrier totals. A few states request supplemental operating statistics for their state alone, but this is not a common practice. Carrier reports to state regulatory agencies are usually similar to or a condensed version of that report to Federal regulatory agencies.
	Deficiencies. Utility of carrier financial data, operating statistics and physical characteristics to statewide systems planning severely limited by (1) the "totals" by carrier orientation of the data (not summarized by geographic area on routes), (2) the unevenness of coverage (excludes private and exempt carriers), and (3) by the types of data being reported (mainly financial). Various proxy techniques have been developed to apply data to performance and economic evaluations. Data important to economic evaluation. Overall, deficiencies judged to be moderate, but surmountable.
Rates/Tariffs	Form. See Appendix E.
	Availability. Full-scale source information on rates and tariffs can be assembled from carrier, rate bureau, and regulatory agency sources.
	Characteristics. The key is knowing how to use published rates and tariff materials, rather than assembling source materials; this knowledge is a speciality all to itself. Even being able to determine the correct rate for a shipment of commodity K between zone i and zone j doesn't indicate the degree to which that tariff or rate is actually used. To be useful in statewide systems planning, tariffs or rates must be simplified through carefully prepared approximations. See Appendix E.
	Deficiences. (1) Lack of readily available reliable simplifications or approximations of rates and tariffs and (2) information on the extent to which different rates and tariffs are actually utilized. Some proxy techniques have been developed to estimate rates or tariffs or revenue data used in lieu thereof. Data important to economic evaluation. Overall, deficiencies judged to be major.

TABLE G-1 (Continued)

Category	Assessments
Transport Level-of-Service Attributes	Form. Two main sources: (1) schedules and guides published by carriers and others on the services offered (frequency of service, routing options, minimum shipping requirements, equipment availability, and special services) which describe the type of service, and (2) the waybill itself from which information can be derived on transport time, time reliability and actual shipping charges. Varies by mode. Loss and damage information normally contained in a separate set of records. Information on waiting time and packaging costs exists only in fragmented forms. Availability. Schedules and guides are readily available, but provide no information on the service actually provided. Waybill data are difficult to obtain, particularly in quantity from which to statistically derive data on transport time and time reliability. Information on waiting time and packaging costs could best be obtained through a shippers' survey. Schedules and waybills are only available for common carriers; similar information does not exist in any standardized form for exempt and private carriers. Characteristics. Varies among the modes and from carrier to carrier. Waybills often do not contain transit time information and actual shipping charges. Carrier records are a far better source of transport time and shipping cost data than the shipper's or consignee's copy of the bill of lading. Deficiencies. Lack of data or difficulty assembling data from waybill records on transport time, time reliability, and actual shipping charges. Not possible for states to assemble their own data on transport level-of-service attributes, best done by research institutions. Data important to long-term understanding of intercity freight flows and the development of modal choice models. Overall deficiencies judged to be major.
Commodity Attributes	Form. Fragmented. References on commodity identifiers and associated physical and seasonality characteristics readily available. Information could also be obtained from manufacturing, extractive industry, and agricultural "experts" in state and local governments. Information on the economic consequences of late or unreliable transport time exists only in fragmented form. Economic consequences include extra costs associated with shelf life, fragility or susceptibility to damage, and product use (inventory control system/costs associated with possible stock out situations.) Mode independent. Availability. Aside from commodity identifiers and physical and seasonality characteristics, which in themselves would require appreciable effort to assemble, very little information exists. Limited information on economic consequences of promised delivery dates available from special studies of inventory control systems. Characteristics. Information on economic consequences in the form of case studies. Deficiencies. Combination of (1) a lack of information on economic consequences, and (2) fragmented information on commodity physical and seasonality characteristics. Not possible for states to assemble their own data on commodity attributes; best done by a research institution. Data important to a long-term understanding of intercity freight flows and the development of modal choice models. Overall deficienies judged to be minor for near term but increasing as states develop capabilities to do more sophisticated freight systems planning.

Category	Assessments
Shipper Attributes Market Attributes	Form. Fragmented. Some information obtainable through economic censuses (e.g. annual production volume, number of establishments, location, size). An input/output transactions table would provide information on industrial interdependencies. The remainder could only be obtained through in-depth shippers' surveys of both bills of lading and interviews with plant officials. Availability. Census information is readily available although in an aggregated form. National-level input/output transactions tables are also available. Little information exists in a convenient form on (1) freight ownership, (2) pricing structures as they affect transportation decisions, (3) shippers' awareness and knowledge of alternative transport mode options, and (4) ownership or loyalities to specific means of transport. Characteristics. Census data are generally too aggregated for statewide planning purposes; data should be aggregated no higher than county or region within state. To determine long-term behavior, time series data are required at a national or multi-state scale. Deficiencies. An understanding of and data on shipper location and market criteria, industrial economists and location experts have not come up with definitive answers useful in transportation systems planning. Not possible for states to assemble their own data on shipper and market attributes; best done by research institutions specializing in business administration and micro-economics. Data important to a long-term understanding of intercity freight flows and demand estimation. Overall deficiencies judged to be minor for near term but increasing as states develop capabilities to do more sophisticated freight systems planning.
Facility Location	Form. Fragmented. Information on maps and in directories gives general location. Information on the type, size, age and general characteristics of the line haul or terminal facility would have to be obtained from the owning carrier or through directories. Varies by mode. Availability. General information on the location and physical characteristics of line haul and terminal facilities can be obtained without difficulty. Data generally must be obtained locally. Characteristics. Extremely variable. Often information is not available in a form desired, or may not be up-to-date or particularly accurate, or access to the information may be difficult. Deficiencies. Quality of information including variability among the modes. Data fundamental to virtually all planning activities. Overall, deficiencies judged to be minor.
Condition of Plant	Form. Varies by mode. Generally consists of internal information describing age, wear, condition, remaining service life, rehabilitation cost and replacement cost. For rail, information indirectly available on track systems in terms of slow orders and other restrictions imposed for safety reasons. State regulatory agencies sometimes have data on track, locomotive and rolling stock conditions obtained through field inspection. State regulatory agencies sometimes conduct safety inspections of trucks. Availability. Most carrier data on the condition of their plant are difficult to obtain. State regulatory agency data would probably be available.

TABLE G-1 (Continued)

Category	Assessments
	Characteristics. Most condition assessments are highly subjective. Condition data are usually not available on a uniform basis. Average ranges from recent and complete, to old or non-existant. Little commonality exists within modes, let along between modes. Deficiencies. Combination of (1) a lack of condition data, and (2) for that which exists, its quality, age, and consistency among competing carriers and across modes. To some extent, the lack of data can be solved through state efforts (physical inspections). Data important to economic evaluation. Overall, deficiencies judged to be moderate, but surmountable through state efforts in digging out such information from carriers or in conducting own condition assessments (with or without state regulatory agency assistance).
Operating Characteristics	Form. Varies by mode. Some information on scheduled performance contained in various guides and schedules issued by carriers and independent publishers. Some information prepared by carriers for use of operating personnel (e.g. railroad employee time tables). Information on actual performance is fragmented. Availability. Information on scheduled performance is available to varying extent. Some modes issue schedules on timetables for public usage, others do not. Little information is available on actual performance, although most carriers collect the data for management and control purposes. Characteristics. Scheduled performance information generally represents ideal situation; actual performance will normally be appreciably less. Deficiencies. Lack of identifiable information on actual performance and difficulty in assembling such information. To some extent, waybill sample data on transport time and time reliability used in lieu of internal records on operating performance or information obtained through a shipper's survey. Data important to economic evaluation. Overall, deficiencies judged to be moderate, but surmountable through state efforts in digging out such data from carriers or Federal and state regulatory agencies.
Usage-Capacity	Form. Usage is normally expressed in density form. Capacity is a calculated parameter depending upon physical characteristics, operating practices, etc. Availability. Varies by mode. Density data can generally be obtained as described earlier. Data needed for capacity calculations comes from a variety of sources. Characteristics. Varies by mode. Density data may be in weight or number of vehicles passing over a particular section of track, highway or waterway. Density values not compatable between modes -- difficult to determine tons or ton-miles. Deficiencies. Usage data can generally be obtained or reasonably approximated. Lack of information mainly on trucks. Information needed for capacity calculations, if desired, generally obtainable. Main problem is not in the data, but how to determine capacity on a practical basis. Data important to network analysis. Overall, deficiencies judged to be minor.

Category	Assessments
Unit Operating Costs	Form. Variety of forms. See Appendix E. Availability. Varies by mode. Majority of data provided by carriers to Federal regulatory agencies through quarterly and annual reports. Appreciable analysis and processing of financial data undertaken by regulatory agencies to develop unit costs. Unit cost data also developed by carriers for internal purposes. Unit cost data also submitted by carriers and rate bureaus to support rate-making requests. Characteristics. Unit cost data developed by regulatory agencies represents average conditions which may or may not be applicable to situation at hand. Carrier unit cost data reflect the unique conditions enjoyed by the particular carrier involved. Most unit operating cost data probably have a sizable variance associated with them; unfortunately, prescribed accounting systems do not readily reflect such variations with location, facility type, etc. Deficiencies. Not so much a lack of data, but rather a multiplicity of conflicting information. Also quality of the data and unevenness of coverage among the modes. Extremely difficult data for states to evaluate, assemble, and use properly. Data important to economic evaluation. Overall, deficiencies judged to be major.
Unit Capital Costs	Form. Ranges from simple, ball-park figures for a unit length of roadbed construction or rehabilitation and average cost of a locomotive, a truck, or a rail car to detailed unit costs based on labor, equipment, and materials components. Availability. Limited. Data available only as a consequence of government investment in transportation facilities or equipment. Characteristics. Data available principally for railroad track rehabilitation and rolling stock and locomotives, waterway construction costs, and highway construction costs. Little data on terminal costs or on aircraft and pipeline costs. Unit cost data generally do not exist as such, rather as bid prices or engineering estimates for recent past or on-going construction projects sponsored by governmental agencies or for which public monies are involved. The uniqueness of infrastructure investments makes unit cost data difficult to assemble. Cost items generally differ from those used in highway construction. Deficiencies. The fragmentation of information on capital costs and the great difficulty and work involved in assembling such unit cost data. Quality of data and unevenness of coverage among the modes. Difficult for states to assemble their own data on unit capital costs due to the variety of capital investments and the limited amount of data on particular types of construction or equipment purchase. Data important to economic evaluation. Overall, deficiencies judged to be major.
Noise, Air Quality, Water Quality	Form. Generally in emission rates per vehicle for various types of vehicles under different operating conditions. Availability. Data vary in availability and quality by mode. Data most available for the highway and aircraft modes and least available for waterway and pipeline operations. Characteristics. Usually, emission rates reflect the different types of power plants in usage and a few "typical" operating situations. Noise data in decibels (dBA) at stated distances

TABLE G-1 (Continued)

Category	Assessments
	from the source, with no consideration being given to the adjacent environment. Vehicle emissions data are in pounds (kilograms) of CO, HC, No_x produced per gallon (litre) of fuel consumed or per ton mile(metric ton - kilometre) -- no consideration given to atmospheric or topographical effects. Impacts on water quality generally related to vehicle miles (kilometres). Deficiencies. Data are not deficient, rather they need to be extended to permit more accurate computation of emissions under actual operating conditions. Unevenness of coverage among the modes. Not possible for states to develop their own unit emissions data. Data important to impact estimation. Overall, deficiencies judged to be minor.
Soil Erosion, Ecologic, Economic, Socio-Political Aesthetic-Visual, Safety-Related	Form. Varies by mode. Availability. Depends almost totally on what is being affected locally. Generalization not possible. Characteristics. Varies by mode and situation. Generalization not possible. Deficiencies. Depends upon the work done by the state to identify, measure, and assess impacts. Data necessary for impact estimation generally available from local sources, may entail considerable staff effort to locate and assemble required information. Overall, deficiencies judged to be minor.
Energy Consumption	Form. Generally in the form of gallons per ton-mile. (litres per metric ton-kilometre). Availability. Data vary in availability and quality by mode. Data most available for highway and railroad modes, least available for waterway and pipeline operations. Characteristics. Usually, energy consumption rates reflect the different types of power plants in usage and a few "typical" operating parameters. Deficiencies. Data itself is not deficient, rather it needs to be extended to include additional power plants and measurements under different operating conditions. Unevenness of coverage among the modes. Not possible for states to develop their own unit consumption data. Overall, deficiencies judged to be minor.

data from multiple sources, and (3) the amount of staff effort involved in assembling the data into a usable form.

- *Characteristics.* Entries describe the general characteristics of the data available as they relate to data needs for statewide transportation planning purposes. Covered are such topics as (1) aggregation, (2) modal variability, (3) coding systems, and (4) level of detail.
- *Deficiencies.* Entries evaluate the degree to which available data sources meet data needs. Entries describe in summary terms (1) the completeness of the data; (2) any overall quality or consistency problems; (3) modal coverage or lack thereof, (4) its use in demand estimation, modal choice modeling, network analysis, economic evaluation, or impact estimation; and (5) whether the identified deficiencies can be met through proxy measures or state-level data collection activities. An over-all assessment was then made by judging whether the deficiencies were minor, moderate, or major.

The over-all assessments are then compared with two other sets of data (Table G-2) to determine the criticality of deficiencies to statewide transportation planning needs. The first two columns show the frequency that the particular data categories are required for transportation systems planning, either through a problems and issues approach (Appendix A), or through the traditional transportation systems planning process (Appendixes B, C, D, E, and F). The third column simply lists the over-all assessment made in Table G-1. The final column shows the criticality of the

TABLE G-2

OVER-ALL CRITICALITY OF DEFICIENCIES, BY CATEGORY

	Data Category	Frequency that Data Are Req'd. for Transportation Systems Planning		Over-all Deficiency Assessment, Table H-1	Criticality of Deficiency and Unmet Data Needs
		Issues and Problems Approach	Quantitative Methods Approach		
TRAFFIC FLOW DATA	Commodity Production	Low	Moderate	Minor	Low
	Commodity Consumption	Low	Moderate	Minor	Low
	Commodity Flow	Low	High	Major	High
	Traffic Flow	Moderate to High	High	Major	Very High
	Vehicle Flow	Very High	High	Minor	Moderate
	Import/Export	Low	Low	Minor	Low
	Routings	Moderate to High	Moderate	Moderate	Moderate to High
CARRIER DATA	Financial	Moderate	Low	Moderate	Moderate
	Operating Statistics	Moderate	Low	Moderate	Moderate
	Physical Characteristics	Moderate	Moderate	Moderate	Moderate
	Rates/Tariffs	Low to Moderate	High	Major	High
SHIPPER/ CONSIGNEE ATTRIBUTES	Level of Service	Low	Moderate	Major	High
	Commodity	Low	Moderate	Minor	Low
	Market	Low	Low	Minor	Low
	Shipper	Low	Low	Minor	Low
PHYSICAL AND OPERATING DATA	Facility Location	Very High	Moderate	Minor	Low
	Condition of Plant	High	Low	Moderate	Moderate
	Operating Characteristics	Very High	Moderate	Moderate	Moderate
	Use-Capacity	Very High	High	Minor	Low
	Unit Costs-Operating	Moderate	Moderate	Major	High
	Unit Costs-Capital	Low to Moderate	Moderate	Major	High
DIRECT AND INDIRECT IMPACTS	Noise	Low to Moderate	Low	Minor	Low
	Air Quality	Low to Moderate	Low	Minor	Low
	Water Quality	Low to Moderate	Low	Minor	Low
	Soil Erosion	Low to Moderate	Low	Minor	Low
	Ecologic	Low to Moderate	Low	Minor	Low
	Economic	High	Moderate	Minor	Moderate
	Socio-Political	Moderate	Low	Minor	Low
	Aesthetic-Visual	Moderate	Low	Minor	Low
	Energy Consumption	Low to Moderate	Moderate	Minor	Moderate
	Safety-Related	Moderate	Low	Minor	Low

deficiency and the unmet data needs. Entries in this column were derived simply through comparing data needs against data supply. Of the 31 categories listed in Tables G-1 and G-2, seven were found to have "high" and nine to have "moderate" unmet data needs. The seven categories with "high" unmet data needs covered commodity and traffic flow data, routings, rates and tariffs, transport level-of-service attributes, and operating and capital unit costs. Strategies for resolving deficiencies for these seven categories are discussed in the following.

STRATEGIES FOR RESOLVING DEFICIENCIES

The remainder of this appendix is devoted to presenting and evaluating strategies for resolving data deficiencies having a high criticality to freight statewide transportation systems planning. Strategies are discussed under four topics: (1) improving traffic flow data (includes commodity and traffic flow data and transport level-of-service attributes), (2) improving information on routings, (3) improving cost data, and (4) obtaining more useful data on rates and tariffs. Under each topic, the following format is used. First, recent developments that attempt to remedy the existing data deficiencies are summarized. These sections will inform states of new advances and plans in the data collection field. Next, practical considerations that must be considered when the techniques for obtaining better data are analyzed are presented in a synopsis form. Finally, alternative strategies are introduced, along with the advantages and disadvantages of each in terms of the amount and quality of information collected and the cost to states.

Improving Traffic Flow Data

Recent Developments

This section briefly reviews recent efforts to improve the quantity, coverage, and availability of traffic flow data. These efforts highlight the inertia and difficulties encountered in translating even very major data needs into ongoing governmental or carrier programs.

The Joint USDOT-ICC Freight Transportation Statistics Study. In 1967, a joint USDOT-ICC program was established to reduce the "data gap" in freight transportation information and improve the availability and usefulness of freight transportation flow statistics (*G-1*).

A joint study group was subsequently formed to carry out the initial two phases of a rather ambitious program. Included were a user survey and the development of plans and specifications for rail and motor freight transport flow statistics. A survey questionnaire was prepared and distributed to carriers, shippers, trade associations, and government agencies to determine the uses and continuing requirements for flow statistics. The responses indicated extensive use of existing flow statistics and justification for improved data. The study group also interviewed a number of key ICC personnel. Little work was done on developing specifications for traffic flow data, however.

The study group did not make any strong recommendations in the final report (*G-2*), which stated the study group opinion that (1) the rail carload waybill statistics program should be continued, (2) existing data should be improved, (3) the collection of transportation flow statistics should be extended to cover all modes of transport, and (4) such a program should be given high government priority. The main achievement of the joint study was the continuation of the rail carload waybill sampling program, which has been discontinued by the ICC as a result of budget restrictions imposed early in 1968.

A National Transportation Flow Statistics Forum. At about the same time, a three-day meeting was held in Washington, D.C. This was attended by industry, government, and academic people concerned about the general lack of adequate transport flow data at the national level. The purpose of the forum was to generate public support and interest in traffic flow data. Conclusions reached included (1) the increased need for accurate transportation and traffic data, particularly with respect to traffic flow, (2) the necessity for standardization of data elements, particularly commodity and geographic location coding systems, and (3) the need to improve the quality and modal comprehensiveness of existing statistical series. The forum proceedings were published (*G-3*) and various recommendations were transmitted to government officials. Unfortunately, the genuine interest and need expressed were not translated into discernible actions.

Commodity Transportation Survey Feasibility Study. In 1973, the Bureau of the Census conducted a study under contract with USDOT, to determine the feasibility of expanding the commodity transportation survey (*G-4*). The present survey is based on a sample of shipments originated by manufacturers. The project consisted of:

- Appraising the feasibility of obtaining specific data that would accurately describe the total elapsed time from origin to destination, the modes used in each part of the movement, delays and causes of delays, costs of shipments, principal sources of uncertainty affecting promised delivery times and similar descriptions of the actual passage of a shipment in some commodities from origin to destination.
- Determining the feasibility of sampling shipments from wholesalers, including merchant wholesalers, petroleum bulk stations and terminals, and assemblers of farm products.
- Determining the feasibility of sampling mineral industry shipments.
- Appraising the quantity and quality of transportation flow data for 530 USDOT transportation traffic zones.

Upon completion of the feasibility study, the Bureau concluded that information on commodity shipping charges and elapsed time could best be obtained from the carriers using "hindsight tracing" procedures, rather than from shippers who are the basic data source for the Census of Transportation. For shipments made by private carriers, Census concluded that the shipper was the only possible source of such information. Extending the Commodity Transportation Survey to include wholesaler, agricultural commodities, and minerals industry shipments was found to be generally feasible.

In 1974, Census conducted a two-stage pilot test of the first three parts of the expansion project. The purpose was

to gain first-hand experience on costs and survey procedures. The first stage was a shipper survey of in-scope minerals and wholesaling establishments. In the second stage, a sample of carriers was selected from the processed and regrouped shipment data and personal visits were made to collect time-in-transit and shipping charge data. Following completion of the second stage the Bureau of the Census undertook a one-time, full-scale survey of farm assemblers and the minerals industry. Wholesalers were eliminated for budgetary reasons. The results from the survey of farm assemblers and minerals industry companies have not been released.

The significance of the expansion project lies in that it demonstrates USDOT's interest and effort toward improving the Commodity Transportation Survey in terms of (1) SIC coverage, (2) detailed content, and (3) sampling-rate, and that such improvements are entirely feasible.

TSC Commodity Flow Data Base. TSC currently has an on-going project to develop an integrated, multi-mode, regional commodity flow data base for use in traffic and operations analysis. The data base is being built from the FRA/ICC waybill sample, the Corps of Engineers waterborne commerce flows, and the Commodity Transportation Survey, all for 1972. Some work has been done by Jack Faucett Associates, Inc. Data were developed based on 173 BEA regions for 23 bulk commodities that account for 80 percent of all tonnage flows. The results of this work are presently being reviewed by TSC.

In preparing the detailed flow matrices, comparisons were made with BEA-prepared economic production and consumption statistics and adjustments made to the expanded data where necessary. A separate effort will be made by TSC personnel to forecast commodity flow data using BEA economic forecasts as a base.

In addition to this effort, TSC has prepared a machine-readable file that combines the results of the 1963, 1967, and 1972 Commodity Transportation Survey. All the results have been corrected and reformated as required to allow comparisons to be made between the three surveys.

Practical Considerations

All of the described recent developments are nationally oriented. Although they are potentially helpful to the states, they nevertheless do not directly address state-level needs for traffic flow data.

This section lists the major factors that bear on alternatives for obtaining better traffic flow data. It strives to reduce to a few essential points the many arguments for and against different courses of action. No effort is made to discuss fully and explain each point made, nor should the following be regarded as all-inclusive.

- Government is dependent on carriers or shippers for traffic flow data; it generates nothing itself. For-hire carriers have the data needed to construct traffic flow matrices, as do major shippers and consignees. Records of private and exempt carriers are less complete; some maintain records similar to those of for-hire carriers; some maintain very little documentation. A similar situation exists for small shippers and consignees. There is no practical way in which government can obtain freight traffic flow data directly.
- Being dependent, government has three source options: (1) carriers, (2) shippers and/or consignees, or (3) both. The feasibility of this varies inversely with the sizes of the universes involved. Obtaining data from regulated carriers is manageable (less so in the case of motor carriers, where there are 15,000 ICC-regulated carriers, 40,000 exempt, and 103,100 known private carriers). The universe of shippers and/or consignees is also large (approx. 100,000 firms for the manufacturing sector alone). Thus, there is no easy option.
- Even with all its inherent difficulties, it is far better to focus on shipments rather than vehicles in measuring traffic flow. The latter approach did not work well either in urban area transportation studies or in FHWA's recent National Truck Study.
- The total number of shipments made each year is so large as to preclude any technique other than sampling. It has been estimated that some 900 million shipments are made each year, the majority of which are by motor carrier (rail accounts for some 25 million shipments). Thus, it becomes essential to focus only on the more significant shipments. There are three ways in which this can be done: (1) by excluding local shipments, (2) by stratified sampling based on the "weight" of the shipment, and (3) restricting the amount of geographic and commodity detail sought in the final product so as to reduce the sample size. The cost of obtaining and processing a sample is probably in the $3 to $5 range (government plus carrier).
- Transport flow data should be collected on a continuous rather than cyclical basis. Present traffic flow data collection efforts result in a mixture of annual and periodic (both random and cyclical) data sets. To be useful for state planning, the amount of data obtained must be substantially increased. This can best be done by routinizing the data collection process analogous to the cycle used by state DOT's in obtaining traffic counts on highway systems. This would permit the use of cross-sectional data in some analyses.
- For planning purposes, it is more important to have even coverage rather than very detailed data for a portion of the universe and little or no data for the remainder. The "gap" problem should be solved first before attempting to improve relatively good data (e.g., the rail waybill sample). The major gap is private and exempt motor carriers.
- Full compatibility of data among the modes and between domestic and international is unlikely to be achieved in the near future. Unfortunately, existing data are classified by several different commodity codes (e.g., STCC and SITC/BTN); the best that can be done in the near term is to develop "bridging" systems to permit ready cross-classification.
- Government presently does not have a satisfactory mechanism for obtaining traffic flow data from nonregulated carriers. Different types of carriers could be identified and, with appropriate legislation, reporting requirements could be imposed. However, the cost and effort involved in obtaining data from the small carriers on a continuing basis

would be prohibitive. Periodic sampling of some carrier groups might prove sufficient.

- Obtaining traffic flow data from shippers or consignees on a universal basis presents more problems than using carriers as the source. Some transport statistics are being obtained from shippers and consignees by the U.S. Bureau of Mines and the U.S. Department of Agriculture. The U.S. Bureau of the Census collects data for the Commodity Transportation Survey from a sample of manufacturers. As discussed earlier, expansion is feasible with wholesaling and mineral industry establishments, untested (and probably less so) with the agriculture sector. For cost and administrative reasons, it is probably infeasible to include the small firm. Census evidently has a satisfactory sampling frame, however. The Census of Transportation, in its present form, could be made more complete by expanding its coverage, at increased cost. Complete coverage, unfortunately, is probably not feasible.

- Although legal and/or regulatory mechanisms must necessarily underlie carrier furnishing of traffic flow data, cooperative government-industry agreement on what is needed and how it should be collected is essential. Carriers must be convinced of the importance and usefulness of aggregated traffic flow data to meet their needs as well as those of government. Because the public need for traffic flow data is difficult to prove conclusively, government cannot impose reporting requirements on regulated carriers without some degree of tacit approval or consent. Present inequity among the modes in furnishing traffic flow data has to be rectified before further requirements are instituted.

- Utilization of standard codes must improve. Utilization of the coding systems being developed by TDCC under USDOT sponsorship will make the assembling and coding of traffic flow data that much easier. Although some of the geographic and commodity detail is not required for statewide freight planning purposes, it should be recorded to permit multiple uses of the obtained information. Data acquisition costs can be held down only as the carriers and industry adopt and implement the standard coding systems as they are developed.

- The on-going computerization of carrier shipping records offers potential for employing complete enumeration for some modes, in lieu of a sample, but that this would be superior to sampling has not been established. Most railroads now prepare, for internal uses, computer tapes containing data on all shipments, which could possibly become the source of complete enumeration. Waterborne commerce data collected by the U.S. Army Corps of Engineers is already computerized, census-type data. But even such apparently complete data present problems. First, the proportion of shipping records which have been computerized, although high among large for-hire carriers, is small in comparison with the total number of shipments made each year. Second, the lack of code and format standardization and variations in information contained therein reduce the value of what could be assembled to the lowest common denominator. Third, shipping documents inevitably contain a high incidence of errors that must be corrected through an audit process. Sampling, on the other hand, retains the advantage of (1) requiring fewer observations, (2) focusing attention on perfecting information on a limited set of movements, (3) establishing uniformity among modes, and (4) being usable in relation to shipper sources.

- Increasing computerization of the control and record-keeping aspect of transport operations will ultimately change present traffic flow data reporting systems. Changes in the method of reporting traffic flow data will come slowly. As electronic communications and billing systems come into use between carriers and major shippers, it is conceivable that some form of data sampling and storage system could come about to obviate manual identification and processing of samples needed for traffic flow data purposes. Provision for this should be built in now as the systems are developed, rather than tacked on later. Such systems may in the long range provide a large portion of the transport flow data.

- There is no way of fully predetermining the potential uses of traffic flow data. Traffic flow data are used for a wide variety of purposes. The characteristics that are important to one user may be immaterial to another. Thus, full flexibility must be retained in summarizing the data to meet specific needs.

- Present traffic flow data do not contain sufficient transport level-of-service and commodity attributes to permit use in mode choice models. This is a frequent complaint of researchers attempting to simulate the mode choice decision process of shippers.

- Of particular concern is the lack of transport cost, transport time, and time reliability data in most sets of traffic flow data. Other level-of-service and commodity attributes would appear to be impossible to obtain on a large-scale basis, because they involve an in-depth probing of the shipper's decision-making process.

- Whereas disaggregate modeling may provide the best basis for replicating shipper mode choice decisions, supporting data are difficult if not impossible to obtain. Data required for disaggregate modeling must originate with either the shipper or the consignee, whoever is deciding the mode ultimately utilized. This requires an on-site probing of the decision-making process; consequently it is time-consuming, costly for both the seeking and supplying organizations and would often be considered an unnecessary intrusion into the confidential operations of the firm. Obtaining such data through a large-scale traffic flow data census or survey would not appear to be practical from a government standpoint.

- Present traffic flow data are directed toward national requirements; they fall short of meeting state requirements because of geographic aggregation. The need is to increase sample size to mitigate disclosure and minimum sampling reliability constraints now restricting the release of traffic flow data. Inasmuch as detailed commodity summaries are not required for freight planning purposes, some trade-off of commodity versus geographic detail (for origins and terminations) would be possible within a given number of observations. To provide satisfactory data at the state level, aggregated to, say, planning regions within a state, a major increase in the number of samples seems inevitable.

- Present transport flow data deficiencies may be viewed, in the main, as constituting the hard core of the data prob-

lems. There is limited possibility for quick fixes. There is no obvious, all-encompassing, total solution to the problem. There is a very difficult trade-off problem to be solved involving (1) data acquisition cost (to shippers and/or carriers as well as the government), (2) the intringement of any survey or census upon the right of privacy, (3) the public interest considerations—is there a sufficiently strong need to know, and (4) the sheer institutional, administrative, and technical considerations involved in establishing the universe and obtaining census or sample information on commodity movement taking place therein. Traffic flow data sought from respondents' records cannot be easily retrieved. The retrieval itself is a financial burden to the respondent, and it may be regarded as an actual or potential breach of the confidential character of the respondent's operations and his relationship with competitors. Then there is the problem of convincing the data-gathering agencies in the federal information ssytem, and congressional appropriation committees, that the required data are of general use or serve administrative objectives, and that the cost to the federal government is not excessive in view of the need or benefits to be gained. Often, exploratory studies will be required to test out promising techniques and solutions.

- Changes in the amount and quality of publicly available traffic flow data will come by degree. A step-by-step process, building upon what has been done in the past seems to be the most practical approach.
- Changes of Federal law are ultimately required to improve transport flow data. First, there must be centralized control and direction, if not the actual collection. Constraints inhibiting the Bureau of the Census from collecting data ostensibly gathered by regulatory agencies, but inadequate for various reasons, must be removed. Disclosure restrictions ideally should be relaxed enough to permit federal and state government use of complete (rather than expurgated) files, with disclosure constraints being applied at the point of public release or dissemination of the results. Arrangements should be worked out to transfer disclosure accountability to states in return for use of basic files.
- Joint federal-state financing is desirable, but should not be treated as a necessary prerequisite to action. This stems from the larger amount of data needed if state as well as national needs are to be met. There is no reason why states should not share in the cost if they are to be the ultimate beneficiaries. On the other hand, the lead time almost mandates unilateral action by the Federal government.

Alternative Strategies

There are five basic options:

- Continue the present *modus operandi,* relying on incremental improvements.
- State DOT initiate state shipper 'surveys to obtain traffic flow data.
- State DOT obtain desired information directly from the carriers operating within that state.
- Create a separate entity—a national transportation statistics center—to be jointly sponsored and supported by government (Federal and state) and carriers.
- Assign the over-all task of traffic flow data to the Federal Government, with responsibility centralized within either the Department of Transportation or the Bureau of the Census (as part of an expanded Census of Transportation).

There may indeed be other options. Those listed are not totally exclusive; combinations are conceivable. Each is discussed in the following in terms of advantages and disadvantages.

Continuation of Present Programs, Relying on Incremental Improvements. This is the easiest course of action, as it requires minimal budgetary and institutional change. It could be viewed as a "do nothing" option. Program extension or improvements would probably take place very slowly; little change has occurred in the rail waybill sample, waterborne commerce statistics, or the Census of Transportation in recent years. On the other hand, if motor carrier data were obtained by this approach and if the rail sample were increased, traffic flow data would be improved considerably.

States Conduct Shipper Surveys. Under this option, states would conduct their own shipper surveys in an analogous fashion to the Census of Transportation.

This arrangement has a number of potential advantages:

- Obtaining of suitable traffic flow data would not be dependent on other organizations. The initiative would lie with the state DOT.
- Selection of shippers or consignees for interview purposes can be directly tailored to the nature of the problem at hand and the information desired.
- Likewise, the type of information sought can be either general or very specialized.
- A survey does not directly involve the carriers; hence, it is useful in situations where carriers would suspect that the information provided might be used against their perceived interests.
- The focus can be directly on the transport decision-making process.

On the other hand, state-conducted shipper surveys do have some disadvantages:

- Surveys are costly to perform and difficult to administer.
- States may not be in a position to develop the universe of shippers.
- It is difficult, if not impossible, to capture overhead traffic (states can only survey shipments originating or terminating within the state).
- It is far more difficult to ensure quality and control in the design and execution of the survey than with a repetitive effort performed on a national basis.
- Surveys now depend completely on voluntary cooperation from shippers.
- Because each state would individually approach shippers for the data it felt were needed, no standardization among states would result. Each survey would tend to be unique, designed to serve a narrow, specific purpose and would inevitably have its own sample design, formats, stratifications, and summarizations. The data obtained

would not be part of a "national" data set; hence, it would not serve national purposes simultaneously with state purposes.

State-conducted shipper surveys have proven to be very useful and necessary to certain types of freight planning, such as branch-line studies. They are particularly useful for specialized, supplemental information from a subset of shippers. The technique conceivably could be used to fill present traffic flow data gaps, such as with private and exempt motor carriers.

States Obtain Traffic Flow Data from Carriers. Under this option, states would directly request from the carriers operating within their borders the traffic flow data deemed necessary for freight planning purposes.

This arrangement has a number of potential advantages:

- Helps establish working relationships by bringing carriers into the freight planning process.
- Bypasses existing traffic flow data systems and offers the possibility of obtaining data having greater coverage (higher sampling rate, or even a census), greater depth (especially in terms of origination and termination coding), and being more current.
- Leaves such problems as confidentiality, disclosure, etc., to be worked out mutually.
- Permits state DOT reimbursement for the computer processing or clerical labor involved, or the use of state DOT personnel in sampling records, extracting desired information.
- Especially useful when only a subset of data is required, such as for a particular corridor.
- Often finesses the problem of obtaining more general, comprehensive agreement at higher levels.

On the other hand, such direct state-to-carrier arrangements do present some disadvantages:

- Because each state would individually approach the carriers for the data thought to be needed, no standardization would result. The data obtained would not be part of a "national" data set; hence, it would not serve national simultaneously with state purposes. Each request would tend to be unique, designed to serve a narrow specific purpose, and would inevitably have its own sample design, formats, stratifications, and summarizations.
- For the larger carriers, there is a real possibility of a multiplicity of requests, which are costly and time-consuming for the carrier to meet, assuming that the carrier is agreeable to releasing the data in the first instance.
- Carriers often are wary of state promises or ability to maintain data confidentiality, because state DOT's must operate in public view. There is a fear of politicians using data to exploit their own purposes at carrier expense.
- There is no clear feeling as to any benefits that may accrue to carriers as a result of sharing data; government has historically been considered more as a foe than a friend (attitude is formed more by regulatory agencies than by executive agencies).
- Data requests depend largely on voluntary cooperation from carriers, although in some cases it is possible to mandate compliance through state regulatory agency directives to regulated carriers.

Obtaining data directly from carriers is easier (1) when good rapport has been established between state DOT and carrier personnel, (2) when the state has demonstrated responsibility and integrity in the use of information provided previously, and (3) when cooperative cost- or staff-sharing arrangements (where collection work at the carrier is done by DOT personnel) minimize the burden of the request on the carriers. Conceivably, this technique would be useful for carriers that are not large enough to use data processing for control and administration.

The Independent Transport Statistics Center Concept. In view of the strong resistance on the part of carriers (particularly motor carriers) to sharing detailed traffic flow data with government for competitive and/or potential misuse reasons, suggestions are periodically made to institutionalize the collection, maintenance, and dissemination of transport flow data outside of government. Under such a concept, in return for provision of data strong safeguards would be created to protect legitimate interests while at the same time making the data available to support planning and research. These safeguards would apply equally to all parties. The data bank created by the Canadian Institute of Guided Ground Transport (CIGGT) partially represents a possible example of the independent transport statistics center concept (see Fig. G-1). By cutting across organizational lines, the concept avoids some of the rivalry and competition within the Federal Government for ownership and control of traffic flow data.

The independent transport statistics center concept does have one major feature not possible through government assumption of the responsibility of providing traffic flow data. There will always be disclosure restrictions of one nature or another. Currently these are applied at the time the data set is summarized. Thus the resulting tabular product has many cells where the entries have been suppressed for disclosure reasons. Researchers, planners, and analysts using the data quantitatively must aggregate the data to that level of detail for which the entries are complete (thus losing a lot of geographic or commodity detail) or attempt to recreate the entries in the cell with the help of data from other sources. This seriously inhibits their work in developing models to forecast use or predict modal choice. It would be far better to let them work with the full data set, applying the disclosure requirements to the output of the process rather than the input. This in effect is the advantage the CIGGT researchers have when using Statistics Canada motor or water carrier data. It does not exist with U.S. Census or Corps of Engineers data.

Extending this concept slightly farther, the statistics center could be not only a depository for traffic flow data, but also a service bureau where center personnel would perform research and analytical operations, using their own or provided computer-based models. In this way, the full data set could be used, making the computations called for by the model while retaining control over what is disclosed through the outputs. It would also encourage specialization and prevent unnecessary duplication in carrying out basic estimating or forecasting operations.

The transport statistics center concept also encourages professional management of the data files. It would permit

FIGURE G-1

EXAMPLE OF THE INDEPENDENT TRANSPORT
STATISTICS CENTER CONCEPT

The Canadian Freight Transport Data Base is an off-shoot from assembling data required to develop and test a Canadian Freight Transport Model (CFTM). (5,6) The CFTM project was originally begun in 1970 under Canadian Institute of Guided Ground Transport (CIGGT) sponsorship (Queens University). Its purpose was to develop a set of analytic planning models of the Canadian freight transportation system with the main focus being on the rail component and the effects of competition from other modes upon railways.

The assembled data base is unique in that it brings together into one consolidated format system traffic flow data for rail, water and motor carrier transport in Canada, with CIGGT-developed common commodity and geographic coding systems supplementing the differing reference systems utilized in the supplied data. (7,8) The detailed statistics obtained were provided in confidence for purposes of CIGGT research by the three major fiscal donors for the year 1970 (data for 1971, 1972 and 1973 are being or have also been supplied). Canadian National and Canadian Pacific Railroads both donated a complete census of waybill movements containing tonnage and tariff but not including time. CN and CP also provided rail car movement data for the CFTM project. Statistics Canada gave a complete census of water carrier movements by commodity giving tonnage and time, but not including tariffs. They also provided the 1970 sample survey of for-hire motor carriers by commodity and tonnages, but not including time. To our knowledge, this data base is the most complete grouping of traffic flow data that has been accomplished anywhere.

Is this an approach; one which could surmount data availability, confidentiality, and disclosure problems which seriously limit state DOT ability to pull together comprehensive secondary traffic flow data? Is the CIGGT data base a good example of the Transportation Statistics Center Concept?

Four factors are involved which make the CIGGT data base a special situation. First, the CIGGT program was initially funded by three parties: the CN, the CP, and the federal government for sponsored research. Each agency has a direct stake and interest in the products or results derived. Hence, if data are needed, it behooves the sponsoring parties to contribute, provided that proper safeguards are taken to protect data given in confidence. This they have done. Second, the data contributors maintain direct control over the use of any data from their contributed files. CIGGT queries them on each proposed file usage. Any objection constitutes a veto. Any vetoed request simply stops file utilization right there. Third, while the data have been assembled, the resulting files have not been used by other than university-connected researchers. The existence of the data base has not been publicized. Neither the federal nor any provincial government has yet requested the use of the data base for freight planning purposes. Thus, the difficult and touchy questions of agency access, data aggregation and release, and ultimate use really have not occurred. Fourth, the geographic and commodity coding schemes common to the four main sets of data automatically result in appreciable aggregation of the data.

Applicability of the CIGGT Data Base Concept to United States

The idea of creating or designating an organization separate from the carriers and government as a neutral third party keeper of the vital statistics on freight transport, especially traffic flow data, has considerable appeal for the following reasons:

Potential government users would hope for

- increased data availability, including sources heretofore unavailable (i.e., motor carrier rate bureau O-D data) through carrier willingness to share data if interests are protected;
- census rather than sample data, especially in view of automated record systems in operation;
- avoidance of aggregation problems, including premature grouping by commodity and/or geography, cell suppression to avoid disclosure, etc., inherent in Census of Transportation data;
- increase the kinds of data available and needed for planning (e.g., transit time, time reliability or variance, shipment value, tariff or revenue);
- availability of more useful statistical series and summaries;
- and elimination of interagency rivalry and overlapping responsibility (e.g., ICC and FRA competition for railroad waybill sample).

Using data for research is a lot different than for governmental planning; it is far easier to maintain confidentiality than in a situation where the public has freedom of access or where special interest groups are seeking data for narrow, possibly ulterior purposes. Also planning ultimately involves public policy issues which at times are going to run counter to carriers' perceived interests. Thus supplied data could very well be used against carriers. This situation rarely occurs in a research situation. While a veto-type mechanism might be set up to provide control over the data, it is hard to maintain confidentiality and accountability necessary to protect data from leakage and potential misuse. Thus we conclude that the CIGGT data base concept is not directly applicable to the problem of finding acceptable institutional mechanism for improving the amount and quality of traffic flow data available to state DOT's.

the development of specialized utility programs to select, sequence, array, summarize, and display the data in any form devised by the researcher. The files, which could be massive and unwieldy if based on census-type data, could be maintained in alternate forms and sequences. Conformance to standard coding systems could be assured. Historical or time series data could also be developed. In short, the motivations for making the data useful could be far greater than in government, where it would be just one of many data files maintained for operational purposes.

Although there are many potential advantages to the transportation statistics center concept, it could be difficult to implement. It essentially requires government-carrier agreement plus legislation not only establishing an independent transport statistics center but also transferring data and functions from existing agencies.

USDOT Be Responsible for Traffic Flow Data. Under this option, different traffic flow data efforts would be consolidated under USDOT aegis. This is not a new idea, the concept of a national transportation data bank having been seriously considered in 1968 and revived on several more recent occasions (see Fig. G-2). The current TSC work fits within this concept as "the development and maintenance of the DOT transportation information base" and "the sharing of technical, social, and economic understanding with the transportation community."

FIGURE G-2

PREVIOUSLY PROPOSED LEGISLATION TO ESTABLISH
A NATIONAL CENTER FOR TRANSPORTATION STATISTICS WITHIN USDOT

On June 10, 1975, Congressman Fred B. Rooney (D-Penna) introduced H.R. 7778, legislation "to help improve and maintain an adequate transportation system through the systematic collection and publication of statistics with respect to the transportation of passengers and freight by railroad and other modes, to establish a National Center for Transportation Statistics, and for other purposes." (10)

The intent of the legislation was to establish a Center under the Secretary of Transportation that would be responsible for (1) collecting and reporting "full and complete statistics" on the conditions of transportation in the United States and in foreign commerce; (2) coordinating Federal collection and dissemination of transportation statistics; and (3) collecting and publishing whatever statistics may be necessary to "Assure a complete statistical picture of transportation in the United States." Expressly stated was the purpose to "assist ... state and local transportation agencies, including regulatory agencies, in improving and automating their statistical and data collection activities." Although traffic flow data were not specifically identified, they obviously were comprehended by the general approach of coordinating statistical and data activities along the other desirable goals such as avoiding unnecessary duplication of statistics collection, developing standardized collection methods, and reviewing and reporting on transportation activities in foreign countries. The Center would be partially funded from service fees collected from the users (except certain Congressional Committees) and would "provide all interested parties, including public and private agencies and individuals, direct access to data ... subject to such conditions as the Director (of the Center) may prescribe." The proposed legislation addressed the states' need for a central source of all transportation data.

On June 11 and 12, 1975, hearings were held before the Subcommittee on Transportation and Commerce on this legislation as well as other matters. The testimony given did not evidence overwhelming support for the Statistics Center within USDOT. For example, the ICC representative stated that while the Commission generally was supportive of the purposes of the legislation, it was unwilling to surrender all transportation data work to the Center and on other points doubted the ability and capacity of the Center to handle the overall task. Similarly, the Deputy Under Secretary of Transportation testified that the Department sees "great merit in the object of the bill" and is ready to assist in achieving the objective; yet, there were some salient points to be cleared up including "problems in how the Federal activities relate to existing state programs and in the protection given proprietary data."

Consequently, no action was taken by the Subcommittee. House Bill 7778 is now dormant and there is said to be no plan, at least for now, of the Subcommittee on Transportation and Commerce to revive the matter. Nevertheless, it is reported that the USDOT maintains at least a latent interest in eventually establishing the Center.

This arrangement has a number of potential advantages:

- It capitalizes on past traffic flow data processing experience and existing staff expertise.
- It places traffic flow data consolidation and maintenance responsibilities within an agency that has a prime need and use for the information derived, as well as technically aiding and financing transportation planning at the state and urban area levels.
- It facilitates improvements and refinements on an ongoing basis.

There are a few major disadvantages, however:

- USDOT is not considered by some of the carriers to be a neutral party; hence, there may be some unwillingness to provide traffic flow data.
- To fully implement and avoid duplication would require legislative changes transferring established programs from other agencies to USDOT. This would be very difficult to accomplish. This might simply rekindle past interagency battles.
- There is always a danger that in developing a truly unified and comprehensive data base, additional and/or duplicatory demands for information would be placed on carriers which, instead of reducing government involvement, would increase it.

USDOT is already working on establishing a consolidated commodity flow data base (*G-9*). It has also undertaken numerous interrelated economic-base studies that depend on transport flow data. A strong case can be made for this particular option.

Expand the U.S. Census of Transportation. The final option involves expanding the present Census of Transportation to become the basic source for traffic flow data. It has the virtue or potential of being the only truly comprehensive approach, provided it is expanded to include the agricultural, mineral, and wholesaling sectors. Were this option to be fully implemented, the coverage, sampling rates, and detail sought on sample shipments would be significantly expanded and the census conducted on a continuous basis. Data on phsyical movements as well as transport expenditures would be obtained. This option must be viewed as long-term; there undoubtedly is appreciable cost associated with expanding the census to become truly useful in state-level freight planning. A shared cost arrangement might be necessary.

Although expansion of the Census of Transportation has been promoted by USDOT, the Bureau of the Census may be taking a somewhat different tack. Recently, the GNP Data Improvement Project staff made a series of recommendations for improving the economic censuses, of which the *Census of Transportation* is but one of nine (*G-11*).

Although no final decisions have been made, an economic rather than physical movement orientation may be in the offing. Some of these recommendations were to be implemented in the 1977 Census of Transportation. Specifically some agricultural, mineral, and wholesaling sectors were to be included.

The major recommendation involving transportation was as follows:

> Absence of data on transportation costs is one of the more serious data deficiencies owing to its critical role in computing gross margins. The deficiency can be traced in large part to the history of subjecting each new type of public carrier of goods to the control of a different regulatory agency or to a different department of the same agency. There is no comprehensive and consistent set of data on all forms of transportation as an industry. The so-called Census of Transportation is a misnomer, limited as it is to a sample survey of waybills and selected passenger's trips. That is, it is a users' survey rather than a survey of the industry's input and outputs. Legislation is probably required to enable the Bureau of the Census or the Department of Transportation to assume responsibility for developing industry-wide statistics that could provide the transportation cost of moving goods from one enterprise to another and eventually to the final consumer.

Improving Routing Data

Recent Developments

In spite of the importance of routing data to transportation systems planning, no known efforts have been made to improve the quality, coverage, and availability of routing data to state DOT's.

Practical Considerations

This section lists the major factors that bear on alternatives for obtaining better routing data. Many of the factors listed earlier under "Improving Traffic Flow Data" apply equally here, hence are not repeated.

- Data on traffic flow over particular routes are extremely scarce. This is especially true for rail and motor carriers where the routing options are the greatest. Routings over the other modes either can be deduced from network and/or ownership characteristics or from available traffic flow data. There are no good sources of complete routing information for railroad and motor carrier freight movement.
- Carriers consider routing information proprietary. Carriers are quite reticent to release any information indicating market penetration. Attitudes differ among the modes. Air carriers are willing to release "aged" information where railroads and motor carriers have consistently resisted government attempts to obtain past or present detailed data on vehicle movements.
- Government has been forced to develop "logical" routings in the absence of actual routing information. Development of logical routings involves (1) estimating freight traffic by mode and carrier between zones, (2) identifying and ranking available routings using a system of "links," and (3) assigning traffic. Such work, conceptually simple, requires an intimate understanding of carrier market penetration and operating practices. State DOT's normally do not have this expertise available internally. Thus, logical routings form a poor substitute for actual data.
- Use of physical measures to estimate "logical" routings usually produces misleading, erroneous information. This is a carryover from urban traffic assignment techniques, where distance, time, or cost are used to determine travel paths. Minimum distance (straight line, great circle, or even short line) does not consider the constraints of insti-

tutional arrangements or the physical network. Institutional factors directly affect chosen routings. For example, a railroad originating traffic for interchange with another railroad routes traffic to maximize its haul and revenue, even though the resulting routing may be highly circuitous compared to the shortest route. Motor carrier instructions are analogous to railroads though more limited Motor carriers are also limited to paticular routes by their operating authority, which may not permit carriers to operate over the shortest practical truck route. A shipper may, as a matter of policy, divide his traffic among competing railroads or motor carriers to foster service competition, even though one routing is longer than another. Also, a shipper may originate different commodities, having different transportation characteristics, which may cause him to use one carrier or mode in preference to another. Thus, railroads, and to a lesser extent motor carriers, are not free to seek the optimum routing in time or distance. Costs are the same, regardless of routing, within mode.

- File size for car movement or routing records is extremely large. In the case of traffic flow data, it is quite possible to maintain complete sets of annual data. This is not possible for car movement records, where the tremendous volume of records precludes any attempt to store such data. A sampling approach is a virtual necessity.
- Until detailed routing data become available, improved network assignment models simply cannot be developed. Actual routing data are required to calibrate traffic flow models. Proxy estimates simply are not good enough. Today, there isn't any other alternative. Hence, with present day models, there is no way of knowing how well they simulate actual operations; thus, the results from these models can only be applied to situations where generalized answers are sufficient.

Alternative Strategies

In this case, the options are similar to those for traffic flow data:

- Continue the present *modus operandi.*
- State DOT obtain desired information directly from the carriers operating in that state.
- The national transportation statistics center concept.
- Assign the task to the federal government, with responsibility centralized either in the appropriate regulatory agency or in the Department of Transportation.

Rely on Incremental Improvements. This course of action has produced limited data in the past.

States Obtain Routing Data from Carriers. Under this option, states would directly request from the carriers the routing data deemed necessary for freight planning purposes.

This arrangement has a number of potential advantages:

- Helps establish working relationships by bringing carriers into the freight planning process.
- May be the most acceptable arrangement to carriers, as it permits sufficient aggregation of data to protect carrier interests while providing to state DOT's the data they need for network analysis and other planning activities.
- For larger carriers, routing data are maintained in computerized form. This permits mechanical extraction of summarization. Carriers would be more willing to do this if their direct costs were reimbursed by the state DOT.

There are also some disadvantages:

- Given the sensitivity of the data, carriers may still be wary of sharing such data with state DOT's. The fear of potential governmental misuse of the data may prevail. Routing data would have to be obtained from all major carriers to be effective in network analyses. Thus, this may not be a practical course of action.
- A request for the data may bring out strong reactions against governmental involvement in planning of what is viewed to be private enterprise. Strongly negative reactions may set back the concept of statewide transportation systems planning.

All-in-all, requesting routing data through cooperative arrangements with carriers appears to be a viable possibility.

The Transportation Statistics Center Concept. See the earlier discussion under "Improving Traffic Flow Data." The statistics center concept applies equally well to routing as to traffic flow data. The example given of the CIGGT data base includes rail car movement data provided by two railroads for model development purposes.

Assign Responsibility to the Federal Government. Again, see the earlier discussion under "Improving Traffic Flow Data."

Improving Cost Data

Recent Developments

Since the early 1970's, the ICC has been studying alternatives to improve the railroads' uniform system of accounts. The Commission is desirous of developing a system of accounts that will provide detail as to the labor, material, and overhead of each account. It is also interested in account information on fixed and variable costs and the assignment of such costs to various functions, services, or activities. The end result will be a completely new approach to cost ascertainment by use of detailed account information to develop costing formulas, rather than the present approach using summary account information and formulas developed on a special study basis.

The ICC published in the *Federal Register* on September 17, 1975, a proposed chart of accounts and supporting schedules. ICC then published in the *Federal Register* on March 31, 1976, a proposed uniform system of accounts for railroad companies which included definitions, instructions, and account tests. Both of these issuances were for public comment. Basically, the reporting system being proposed is a matrix system that will classify operating expense accounts into labor, material, and overhead components, which are then distributed in various functional activities.

The Rail Revitalization and Regulatory Reform Act of 1976 provides impetus to the proposed revision. Specifically, Section 307 sets forth a requirement that the Commission shall prescribe a uniform cost revenue accounting and reporting system for all railroads to be effective not later than January 1, 1978.

Practical Considerations

This section lists the major factors that affect obtaining better information on both capital and operating unit costs.

- Government is dependent on the carriers for raw cost data; it does not itself generate such information. It does digest, organize, and publish the data.
- Great variance exists in the amount of information available among the modes. This depends largely on the amount of government regulation or financial involvement with their concurrent reporting requirements.
- Regulatory agency data were not designed for costing purposes. The accounting systems of carriers and their reports to regulatory agencies provide information to monitor the earnings of carriers, especially balance sheet data. The accounts were not designed to provide the detail necessary for refined cost analyses. Hence, much of the current cost-finding effort results from trying to make do with inadequate base data.
- Costing efforts suffer from too many data and too little knowledge of the data at hand. Organization of existing data is very important. A real need exists to assemble, review, assess, and choose the best data from among competing sets. A similar need exists to document the procedures and assumptions used to develop unit cost data sets. This would ultimately reduce the number of independent data sets and the conflicts that arise from multiplicity.
- Unit cost data sets are often not maintained or adapted to general use. Some of the best work done in developing unit cost data has been done by means of special, one-time studies. The resulting cost data rapidly become dated and stale if not periodically updated. Likewise, little provision is made to apply national or territory unit cost data to specialized situations through carefully developed adjustment procedures.
- Cost data must be simplified and adapted for use in transportation systems planning. Much work could be done to present unit cost data in easy-to-use forms such as graphs, nomographs, equations, etc. There may also be ways of computerizing the storage and access of unit cost data.
- Cost data typically report yesterday's costs, not those likely in the future. There is a great need to develop systematic ways of adjusting recent, but nevertheless historical, cost data to reflect the current or future situation.
- Not enough attention is given to cost data. All too often, the acquisition of unit cost data is put off until too late. Consequently, there is a tendency to accept any set of data in the interest of getting the job done. Cost-related numbers tend to be accepted at face value, rather than carefully examined for accuracy and consistency. Acquisition of cost data should be organized as an on-going activity.

Alternative Strategies

In this case, there are three main alternatives:

- Continue the present *modus operandi.*
- State DOT work with state regulatory agencies and carriers to develop its own unit cost data.
- Designate a federal agency or an independent organization to assemble and maintain unit cost data in a form useful to state DOT for transportation systems planning purposes.

Rely on Incremental Improvements. This course of action has not produced useful unit cost data in the past. Although improvements are being made in industry accounting systems, such changes may not produce unit cost data suitable for statewide systems planning. Furthermore, such changes are still some time in the future.

States Work Out Their Own Arrangements. Under this option, state DOT's working with the state regulatory agency and carriers would develop unit cost information needed for planning purposes. Several different levels of state involvement are possible in assembling and maintaining unit cost data. These options are:

- Simple assembly of readily available "operating" unit cost data, with little or no state assessment of its strengths or weaknesses. Obtain data on infrastructure costs only on an as-needed basis.
- Pulling together alternate sets of unit cost data plus any documentation explaining the data. Staff study and understanding of the different data sets. Limited data on infrastructure costs obtained for facilities where state investment is possible.
- Substantial synthesization of unit cost data based on thorough investigation and knowledge of the strengths and weaknesses of standard data sets and significant one-time or periodic cost analyses plus obtaining supplemental data from carriers. Data storage could be either hard copy or computerized files, depending on its anticipated use. Reasonably complete data would be obtained for infrastructure cost to permit the simulation, evaluation, and comparison of alternative systems. Close working relationship with carriers backed up by legal authority to subpoena necessary data.

Under these options, the level of detail for assembled unit cost data would vary from relatively gross to rather fine-grained cost estimates. There will be occasional instances where even the finest generalized unit cost data are inadequate; in such cases, there is no option other than assembling the required site or line-specific data.

Some of the advantages of this arrangement are:

- Helps establish interagency and state DOT-carrier working relationships.
- State DOT retains control, initiative. Thus cost data can be tailored to the specific situation, and can be produced when and where needed.

The disadvantages include:

- Tends to generate additional data sets. Not only is this wasteful of time and manpower, but it also gives rise to duplicative, conflicting data sets.
- Given the sensitivity of the data, carriers may be reluctant to share such data with states.
- The over-all expense of establishing a strong capability in this area.

Centralized Unit Cost Data Compilation and Distribution. Under this option, a federal agency or an independent organization would assemble and maintain unit cost data

that could then be provided to state DOTs and other users of these data.

One possibility might be a handbook of facts containing a full set of unit cost data in a form readily usable by planners or analysts. Such a handbook would be updated periodically by the issuing organization. It would fully describe and document the sources of data used, assumptions made, and any adjustments necessary to adapt data from other sources. It would carefully explain how the data could be modified to reflect regional differences or any unusual circumstances surrounding the specific application. It would also explain how to update the data to reflect current or future conditions. Compilation of such a handbook would greatly reduce the need for states to individually collect and assimilate unit cost data.

It should be noted that many of the standard reference materials used for information purposes are assembled, printed, and distributed by private organizations on a for-profit basis. A centralized unit cost data compilation and distribution service simply extends this concept to include data of particular interest to state DOTs engaged in freight transportation systems planning.

Some of the advantages of this arrangement are:

- Availability, cost, and quality of information produced by an organization specializing in cost data over that done on a decentralized basis.
- Greater credibility and acceptance of the unit cost data being utilized than if they were prepared by proponents or opponents of a particular project, program, or policy.
- Reduces the need for maintaining such expertise within state DOTs.

Disadvantages include:

- The inertia and difficulties involved in persuading a federal agency or organization to undertake such a program. Obtaining necessary financial support (if required) from federal agencies and state DOTs to underwrite the service.
- Obtaining regulatory agency and carrier cooperation in providing detailed data on unit costs.

Improving Rate Data

Recent Developments

Some study of rate simplification and computerization has been undertaken by the federal government (*G-12*). For the last 15 years or more considerable effort has been directed toward computerization of rate-finding activities. Early studies disclosed need for (1) standardization and (2) tariff simplification to facilitate computerization. Studies have been made of tariff simplification, both in terms of improving the logic in tarff structures and in reducing rates to formula. Some tariffs have been computerized and many shippers have developed ways of employing the computer to facilitate access to frequently used rates. But progress is slow, partly because of inertia and, more importantly, because of the complexity of the task and the cost of accomplishing it. Although tariff users, both carriers and shippers, foresee benefits from simplification and computerization, it is not at all clear that these are cost-effective.

Practical Considerations

This section lists the major factors that bear on alternatives for obtaining better revenue or rate data.

- Government is dependent on carriers or rate bureaus for such information. Although rates are filed with regulatory agencies, it has been difficult for such agencies to retrieve this information. The carriers, working directly or through publishing companies, apparently are in a far better position to provide this information. Only regulated carriers are required to file their rates.
- The subject is a specialty all to itself and is not one that states should venture into without careful preparation. Knowledge of rates is not a skill that can be acquired readily by in-house personnel.
- The real barrier to obtaining information on rates is the complexity of the tariff structure. Improving of rate data is dependent on gaining shipper and carrier acceptance of the concepts of rate simplification and computerization. Until this is done, change is unlikely. Rate simplification and computerization must be viewed only as a long-term possibility.

Alternative Strategies

In this case, there are three main alternatives:

- Continue the present *modus operandi*.
- State DOT work out its own ararngements to obtain revenue or rate data.
- Federal leadership in (1) promoting rate simplification and computerization, (2) acting as a resource to state DOTs for information on rates and tariffs, and (3) support research designed to produce better rate generation models.

Rely on Incremental Improvements. Unfortunately, little incentive exists for simplifying rates and tariffs. Hence, this course of action is not likely to produce significant results, at least in the near future.

State DOTs Work Out Their Own Arrangements. Under this concept, state DOTs would (1) hire necessary experts to develop necessary rate information, (2) obtain the services of regulatory agency personnel familiar with rates, or (3) over a period of time develop internal expertise. This approach would work satisfactorily where the needs for such data were limited. It would not be particularly satisfactory when the data are needed for systems planning purposes.

Federal Leadership in Developing Resource Data and/or Methods. Under this alternative, the Federal government would assume leadership in developing tools for estimating rates and tariffs in addition to promoting rate simplification and computerization. Such tools, which might consist of computerized rates, an information retrieval system, or a series of formulas for estimating rates, would be available to both Federal and state government personnel. This possibility is clearly the most intriguing, as it represents the centralization and dedication of effort required to resolve the unmet data need.

Some of the advantages of this arrangement are:

- Availability, cost, and quality of information produced by an organization specializing in rate data over that done on a decentralized basis.
- Reduces the need for maintaining such expertise within state DOTs.
- Data would be useful for many purposes other than systems planning.

Disadvantages include:

- The inertia and difficulties involved in persuading a Federal agency to undertake such a program. Obtaining necessary financial support (if required) from Federal agencies and state DOTs to underwrite the service.
- Does not include rates for which filing is not required.

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APPENDIX H

BIBLIOGRAPHY

This appendix is a bibliography on freight transportation planning containing 432 entries from books, articles, reports, and other source materials. Each entry includes complete bibliographic data alphabetically arranged by author and cross-referenced by seven subject categories, including: (1) demand forecasting, (2) modal choice analysis, (3) network analysis, (4) economic evaluation, (5) impact estimation, (6) data related, and (7) general or miscellaneous.

The references cited in this bibliography are generally available from the publishing agency. The government reports are generally available through the National Technical Information Service (NTIS) or the U.S. Government Printing Office (GPO). Where this is the case, the document's accession number (i.e., PB — —) appears immediately following the citation.

Subject Key

The subject categories used in this bibliography are as follows:

G. —General
D.F. —Demand Forecasting
M.C. —Mode Choice
N.A. —Network Analysis
E.A. —Economic Analysis/Evaluation
I.E. —Impact Evaluation
D.R. —Data Related
D. —Data
B. —Bibliography

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1/ Subject Key

- G. - General
- D.F.- Demand Forecasting
- M.C.- Mode Choice
- N.A.- Network Analysis
- E.A.- Economic Analysis/Evaluation
- I.E.- Impact Evaluation
- D.R.- Data Related
- D. - Data
- B. - Bibliography

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