Appendix B

Reviews of Freight Demand Forecasting Studies

Appendix B. Reviews of Freight Demand Forecasting Studies

■ B.1 General Overview of Freight Demand Planning: Policy Issues to Be Addressed

General Overview of Freight Planning Process: Relevant Policy Issues

Frank Southworth, Yong Jae Lee, Cynthia S. Griffin, and David Zavattero, "Strategic Motor Freight Planning for Chicago in the Year 2000," *Transportation Research Record*, No. 920, 1983, pp. 45-48.

This paper focuses on freight planning in a metropolitan area. The policy decisions such as the clustering of for-hire freight terminals, channeling heavy freight vehicle flows along a designated truck-route network, and an expansion of a motor carrier commercial zone are investigated.

The study provides examples of the kinds of policy decisions and needed tools that are relevant for urban transportation planners.

Alternative Planning Approaches: Structural and Direct

Cambridge Systematics, Inc., *Statewide Freight Demand Forecasting*, NCHRP 20-17, May 1980.

This report divides freight demand forecasting into two basic approaches: a structured approach and a direct forecasting approach. The structured approach is comprehensive. It recognizes that freight demand is derived from underlying economic activities and subject to intermodal and intramodal competitive forces and government actions. It involves a comprehensive linkage of current or long-range economic activity, production and consumption nodes, distribution or linkages between production and consumption nodes, mode choice and shipment size decisions, vehicle trips, and route assignments.

The challenge of effective execution of the structured approach is that there is no consistent source of data for each of the components of the approach. The authors state "all of the pieces of the structured forecasting approach exist in varying degrees of completeness, integration with other components, and public availability." Furthermore, most of the existing components are based on national data, not state data. The authors argue: "These various models are not designed for state or local applications, have diverse and sometimes incompatible data requirements, are not maintained by any government agency for use by freight transportation planners outside the developing agency and, and are frequently not specified with the goal of implementation within a larger system of freight demand analysis."

Direct forecasting methods are defined as those which ignore (to varying degrees) some of the interrelationships that are analyzed in the full structured model – i.e., interrelationships among long-range economic activity, production and consumption, distribution among production and consumption nodes, mode choice and shipment size, vehicle trips, and route assignment. The direct forecasting approaches are generally tailored to the needs of a particular component of the structured model and fail to account for all of the variables considered in the structured approach. The authors state: "It is useful to think of direct forecasting techniques as simplifications to the structured approach described above, where only a subset of the possible interrelations are examined in detail.

A major limitation of direct forecasting methods is their inability to analyze a wide range of problems. Because they do not consider all the complex interrelationships that are part of the structured analysis, the direct forecasting methods must make simplifying assumptions that limit the complexity and variety of problems that they can deal with.

The authors conclude: "Direct forecasting approaches have been and will continue to be the mainstay of state and local freight transportation planning. While direct forecasting techniques can, in principle, incorporate all of the independent variables found in the structured forecasting approach, limits on empirical model building will force the analysts to limit attention to a subset of possible interactions....The analyst must recognize the true structure of freight demand and decide, based upon agency objectives, planning issues, and resources, which aspects of the structure will be emphasized and which will be de-emphasized or ignored altogether."

B.2 The Structural Approach: Freight Planning Patterned After the Urban Planning Process – Trip Generation, Trip Distribution, Mode Choice, and Route Assignment

1. Overview of Similarities between Freight and Urban Planning

Guidebook for Comprehensive Freight Planning: Four Step Urban Planning Approach Applied to Freight Planning

Frederick Memmott, Roger Creighton Associates, *Application of Freight Demand Forecasting Techniques*, National Cooperative Highway Research Program, Report No. 260, 1983.

This NCHRP Report presents a methodology for states to use in conducting freight studies to be used to meet a wide range of needs including: facility, service, or regulatory problems; state policies toward infrastructure investment, energy use, life cycle costs; and freight components of statewide master plans.

It appears to be the most recent and comprehensive effort to assist states with freight demand forecasting. As such, it is very relevant for our current study. It would be useful to have more information on how this report has been used by states. The report, itself, includes several prototypes of how the procedures suggested can be implemented to solve practical transportation questions. It would be relevant to determine how many additional applications resulted from the suggested procedures. It would also to know if the outlined procedures have been updated or whether such an updating is a desired output of the current NCHRP effort.

This report provides a user manual of the three steps involved in freight forecasting. These steps are borrowed from the urban transportation passenger travel forecasting model. They include: freight generation and distribution; mode choice; and traffic/route assignment. Each of these components is described in detail in a separate chapter of the study. There is a complete reporting of the state-of-the-art developments in each component. Specific references are provided for each of the individual model components. There is a description of how to accomplish each component of the model regardless of the type of data that are available for the state.

The first step in the freight planning process is freight traffic generation and distribution. This involves estimating current volumes of traffic and flows of different types of traffic between specific origins and destinations.

Accordingly, a base case commodity flow matrix is developed. This is used as the basis for making projections and future year commodity flow matrices. A variety of options are available to move from the base year to the future year matrix. One is to project future traffic flow directly from the base year matrix. A second is to project commodity production and consumption on an individual commodity basis and adjust the commodity flow matrix accordingly. A third is to forecast macro-economic indicators and adjust the base year commodity flow matrices.

The next step is modal division, i.e., splitting commodity movements among competing modes. Again, a variety of options are available to accomplish a modal division. Modal cost and rate comparisons can be developed and employed as the basis for splitting the traffic. The comparisons of modes can also be made from the perspective of shipper logistics. The author provides some detail regarding the available methods for costing of the services of different modes.

While claiming to be a user's manual, the study appears more like a catalog of state-of-the-art developments in freight forecasting. It seems clear that any state wanting to initiate a specific freight study using this report would still need the services of an outside consultant to link the individual components in a comprehensive fashion. There are a lot of individual pieces and good advice about the relevant ones depending on the specific circumstances, but insufficient guidance on the linkage across components or the development of an integrated package.

This is not a user-friendly, how-to integrated freight package.

Guidebook for Comprehensive Freight Planning: Four Step Urban Planning Approach Applied to Freight Planning

Frederick W. Memmott and Russell H. Boekenkroeger, "Practical Methodology for Freight Forecasting," *Transportation Research Record,* No. 889, 1982, pp. 1-7.

The authors present a straightforward procedure for freight forecasting. This is a more condensed format of the methodology and approach outlined in NCHRP Report No. 260.

It is driven by a base case commodity flow matrix. Added onto this are cost and rate data for the individual transportation modes. The heart of the model lies in a series of basic cost and revenue relations or estimating equations – one applicable for each commodity-flow/routing possibility.

In summary, this provides a fairly simple, yet practical method for freight forecasting. The authors note that current techniques for modal choice forecasting remain very elementary and are not yet suited for inclusion in freight forecasting models.

Application of Four Step Urban Planning Model Approach to Freight Planning

T. John Kim and Jere J. Hinkle, "Model for Statewide Freight Transportation Planning," *Transportation Research Record*, No. 889, 1982, pp. 15-19.

The authors employ the standard urban transportation modeling process to the freight area. That process involves essentially four steps: trip generation (total volumes), trip distribution (origin-destination commodity flows), modal split, and route assignment.

The authors don't provide details beyond a general sketch of how the elements of the urban transportation modeling process can be adapted to the freight modeling situation.

D. Kurth, *et al.*, *A Research Process for Developing a Statewide Multimodal Transportation Forecasting Model*, prepared by Barton-Aschman Associates, for the New Mexico State Highway and Transportation Department, Santa Fe, August 1991.

This report presents the results of a two-day, April 1991, workshop intended as the first phase of an effort to produce a statewide multimodal forecasting model. The workshop produced a proposal for an effort that would focus on producing an intercity passenger model and a goods movement model. The latter was envisioned as a three-stage model consisting of: commodity generation; commodity distribution and mode choice (combined); and assignment. New Mexico subsequently provided Barton-Aschman with funds to begin development of this model; however, this effort has since been placed on hold, and no further reports have been issued.

2. Trip Generation and Trip Distribution

A. Forecasts Based on Macro-Economic Data

Trip Generation and Trip Distribution: Forecasts of O-D Freight Flows Using Various Macro-Growth and Micro-Production Models.

David P. Middendorf, Mark Jelavich, and Raymond H. Ellis, "Development and Application of Statewide, Multimodal Freight Forecasting Procedures for Florida," *Transportation Research Record*, No. 889, 1982, pp. 7-14.

Beginning with base year freight origin-destination volumes by type of commodity, information from input-output models, forecasted personal income, forecasted industry earnings, in combination, are used to give commodity consumption growth and production growth. These growth projections are combined with the base year tables to give projected origin-destination volumes by type of commodity.

The authors also indicate that efforts to develop a modal split model through a logit formulation were unsuccessful. The difficulties associated with development of a modern discrete choice modal split model seems to be a common observation across a number of these studies.

Jack Faucett Associates, Inc., *California Freight Energy Demand Model*, California Energy Commission, 1983.

H. Weinblatt, "The California Freight Energy Demand Model," *Transportation Research Record*, No. 935, 1983, pp. 26-32.

The California Freight Energy Demand (CALFED) Model uses estimates of base-year truck stock and rail freight and truck activity in five regions of California and forecasts of changes in California production and employment by sector to produce forecasts of changes in truck stock and rail freight and truck activity. Truck activity is estimated by vehicle size class and trailer/body type for freight and non-freight purposes (combined). Rail freight activity is estimated for trailer-on-flatcar service and seven types of carload freight. Diversion of nonlocal freight between truck and rail is estimated using forecast changes in relative costs and pseudo-elasticities for ten commodity groups using aggregate data from the 1977 Commodity Transportation Survey and from other sources. The disaggregate forecasts of truck and rail activity and truck stock are combined with exogenous forecasts of fuel efficiency and fuel prices by fuel type to produce forecasts of truck and rail freight energy demand.

Forecasts of O-D Flows Based on Input-Output Models

G. Treyz, B. Stevens, and D. Ehrlich, *A State Core Forecasting and Policy Simulation Model*, NCHRP Project 8-15A, Handbook 2, Regional Science Research Institute, July 1982.

This is the second of two handbooks produced to facilitate use of input-output models by state transportation planners. In this part of the study, more attention is placed on using IO as a forecasting and policy simulation model (FPSM). In addition to its potential usefulness in assessing the economic impacts of transportation investment, these techniques could also be used to assess the effects of transportation policies such as an additional tax on motor fuel. Computer programs were also supplied with the handbook. In this regard, the results could fit with a comprehensive structural approach to forecasting impacts of policy changes. However, it appears that these input-output models have been little used for actual state planning activities.

Jack Faucett Associates, *The Department of Transportation Long-Range Forecast Model*, U.S. Department of Transportation, Office of the Secretary, January 1980.

The Department of Transportation Long-Range Forecast Model consists of an input-output model (the INFORUM model of the University of Maryland) and a transportation submodel, with detail for 31 commercial and private transportation modes. The submodel calculates output levels for the transportation modes consistent with the economic projects and industrial detail from the main model.

The transportation submodel distinguishes six major modes for transporting domestic intercity freight (rail, commercial and private trucking, inland and coastal water, and petroleum pipelines). A modal split model incorporating own and cross-price elasticities is used to estimate modal diversion among the first four of these modes (rail, inland water, and the two truck modes) resulting from changes in modal costs. Other modes distinguished include air freight, international water freight, commercial and private local trucking (separately), non-freight trucking, government trucking, and transportation services and warehousing. Total freight traffic is estimated separately for 48 commodity groups using INFORUM forecasts, with additional analyses performed for grain, coal, crude oil, and petroleum products.

Passenger transportation forecasts are exogenous and are specified as inputs to the transportation submodel. The transportation submodel also calculates input requirements for each transportation mode, including detailed inputs of fuels.

Forecasts of O-D Flows Based on Reebie and Rail Waybill Data

V. Eusebio and S. Rindom, *Interstate Movements of Manufactured Goods in Kansas*, Kansas Department of Transportation, May 1991.

This study was done for the purpose of determining the flow of manufactured goods between Kansas and various origins/destinations, and also to determine the flows of goods moving by rail and truck. The Reebie Associates Transearch data base was used for truck data, while the ICC Waybill tape was used to obtain rail data. The bulk of the report is a series of 57 tables noting various commodity flows. This type of state study points to the value of providing better access to the states for rail and truck flows data.

B. Flows Based on Linear Programming Models

Trip Generation and Trip Distribution Forecasts Based on Linear Programming Models

Mary Marchant, "Analysis of the Effects of Rising Transportation Costs on California's Fresh Fruit and Vegetable Markets," *Journal of the Transportation Research Forum*, Vol. XXXII, No. 1, 1991, pp. 17-32.

This article looks at a linear programming model to allocate freight (i.e., competitive agricultural crops) among several producing regions and various markets in order to minimize total costs (the sum of production and transportation costs) subject to various production and consumption constraints. In particular, the model analyzes the impact of rising transportation costs (from increased fuel prices) on California's produce market share. The analysis suggests the complexity of analyzing impacts of factors such as changing fuel costs on freight traffic flows.

The implication of this type of study is that freight allocation models could go beyond taking a base set of freight flows adjusting for prospective changes in the economy and changes in modal split to utilizing an input-output framework and incorporating changes in shipping patterns as this study has done for produce.

Trip Generation/Trip Distribution: Linear Programming and Network Approach

Michael Florian and Teodor Crainic, editors, *Strategic Planning of Freight Transportation in Brazil: Methodology and Applications*, University of Montreal, July 1989.

This study lays out a comprehensive network modeling approach toward strategic planning for freight transport services. Network model methods are used to simulate flows, service levels, and costs for alternative modes. The models used are multi-product, multi-commodity network flow problems. The transportation system is specified in terms of links and nodes with given capacities among them. Added to this are data on service and cost characteristics of each mode as well as origin to destination demands for products.

The output of the model are flows on a particular mode between a particular origin and destination on the network. The study provides detailed analytical procedures and applications in the Brazilian context. This type of methodology is quite complex and may be extremely difficult to transport to other regions/nations. It was designed specifically to use available data from Brazil.

Trip Generation/Trip Distribution: Linear Programming and Network Approach

Jacques Guelat, Michael Florian and Teodor Crainic, "A Multimode Multiproduct Network Assignment Model for Strategic Planning of Freight Flows," *Transportation Science*, Vol. 24, No. 1, February 1990, pp. 25-39.

This provides a journal-length description of the full study discussed above. The authors point out that previous uses of network models have been confined mainly to urban transportation studies for prediction of passenger transportation flows within an urban area. Less attention has been given to the freight flow problem as a result of the inherent complexities of freight transportation.

Spatial price equilibrium models have been previously used for predicting inter-regional freight flows. This study uses network models. One aspect of this network model which differs from previous work is that individual shippers and carriers are not identified explicitly. This type of approach is more appropriate for strategic planning at a national level.

This article provides a good review of network models and their use in freight planning applications. From a network modeling standpoint, there are a number of technical innovations associated with the Brazilian project.

Trip Generation/Trip Distribution: Combination of Approaches – Manufacturing Data, Network Modeling

W. Black and J. Palmer, *Transport Flows in the State of Indiana: Commodity Database Development and Traffic Assignment Phase I*, Transportation Research Center, Indiana University, February 1993.

This study is one of the most sophisticated modeling exercises done by or for state transportation departments. The purpose is to produce an extensive analysis of key rail and highway flows in the state of Indiana. Network models are used, drawing from the FHWA highway network model and the Census TIGER files. Data was drawn from the ICC Waybill tapes, energy data bases, grain flow data and the now somewhat dated 1987 Census of Manufacturing tapes. One use of the study is to designate key highway corridors for upgrading and maintenance. Indiana is continuing with follow-up studies for more accurate determination of traffic flows. This study suggests that national freight data, made more readily available to the states, would be of use in such studies. In particular, truck flow data is very critical for planning purposes and difficult to obtain. It also points to the potential usefulness of updated and more readily available rail and highway network models. It should be noted that this study did not involve forecasts of future flows, but only determination of current flows.

C. Various Forecasting Methods

Trip Generation and Trip Distribution: A Survey of Methods Used to Predict Future Trends

David V. Grier and L. Leigh Skaggs, *A Review of 16 Planning and Forecast Methodologies Used in U.S. Army Corps of Engineers Inland Navigation Studies*, U.S. Army Corps of Engineers, Water Resources Support Center, Institute for Water Resources, Fort Belvoir, Virginia, June 1992.

The projection methodologies of the 16 studies reviewed as part of this effort fall into four broad groups: (1) the application of independently derived commodity-specific annual growth rates to base year traffic levels; (2) shipper surveys of existing and potential waterway users to determine future plans to ship by barge; (3) statistical analysis using regression and correlation to predict future waterborne traffic based on independent economic variables; and (4) a detailed long-range commodity supply-demand and modal split analysis incorporating the production and consumption patterns of individual economic regions within the waterway hinterland.

The basic focus of these studies is the prediction of traffic on all, or a portion, of the inland waterway system. As such the studies lack the comprehensiveness of the integrated structured approach outlined in the Statewide Demand Forecasting study.

The authors ask the question: "What is the best kind of method" for forecasting inland waterway traffic. The authors set some assessment criteria: the most practical methodology appears to be one that uses a consistent set of macroeconomic assumptions in generating international, national, and regional level projections. Methodology should be easily updatable based on latest historic and forecast data, be relatively low-cost for the project manager to implement, and be PC-based.

The authors find that "the methodology incorporating commodity-specific growth rates applied to one or more base year traffic levels appears to best meet the established criteria." In contrast, methods which rely on shipper surveys tend to build in an optimistic bias and do not sufficiently address long-term forecast issues. Statistically based regression and correlation methods inherently assume a continuation of past trends. Finally, a long-term evaluation of regional market demands, resource bases, production levels and transportation modes, while detailed, extensive and methodologically defensible – is unfortunately the type of massive forecasting effort that is not easily updated and may be impractical for smaller planning staffs.

Unfortunately, these commodity-specific top-down growth rate projections are often too general to be disaggregated to the local level without a serious loss of reliability. However, the authors believe that this forecast method can be used to provide a consistent national framework that can be refined in a project level analysis by planners equipped with knowledge of local industry, markets and transportation patterns.

Sources of Truck Data for Determining Trip Generation/Trip Distribution

P. Hu, T. Wright, S. Miaou, D. Beal, and S. Davis, *Estimating Commercial Truck VMT of Interstate Motor Carriers: Data Evaluation,* Oak Ridge National Laboratory Report, November 1989.

Data availability is a key issue for freight forecasters, and this report provides information about a number of data sources for commercial trucks:

1. Truck Inventory and Use Survey from the Bureau of the Census

2. Nationwide Truck Activity and Commodity Survey from the Bureau of the Census

3. National Truck Trip Information survey from the University of Michigan Transportation Research Institute

4. Highway Performance Monitoring System form the FHWA

5. State fuel tax reports from each individual state and the International Fuel Tax Agreement

6. International Registration Plan of the American Association of Motor Vehicle Administrators.

This report evaluates each of these data sources in subsequent chapters, with particular attention to the ability of each source to estimate vehicle miles of travel by carrier type and by state. This type of data is useful for determining accident rates, highway investment needs, and economic impacts of FHWA policies. The report would also be useful for anyone seeking further details on truck data sources.

3. Mode-Split/Mode Choice

A. *Aggregate Approach Mode-Split/Mode Choice Model: Aggregate Approach*

Michael W. Babcock and H. Wade German, "Changing Determinants of Truck-Rail Market Shares, *Logistics and Transportation Review*, Vol 25, No. 3 (1989), pp. 251-270.

This analysis provides an equation to estimate rail market share as a function of rail/truck rate and service comparisons, macro-economic interest rates, and a time trend variable. The equation is estimated separately for a pre- and post-1980 time period.

There is an equation to estimate rail market share in each two-digit STCC classification aggregate annually for the entire United States. While data are available on rail tonnage by commodity, truck tonnage, and, therefore, gains or losses in traffic, is imputed by comparing rail tonnage with total industrial production.

The authors rely on time dummy variables to estimate the effects of such factors as a shift to just-in-time production, changing oil prices, and changes in size and weight regulations on market share changes between rail and truck. The single time dummy variables does not allow the researcher to untangle or to measure explicitly the impact of each of these factors individually in the model.

This technique provides a rough, aggregate measure of changes in market share between rail and truck. It deals only with some broad, overall measures and provides little insight into the incremental contribution of specific factors. Furthermore, the broad product categories employed make mask many differences that exist in each of the disaggregated product categories.

Freight Demand/Mode Split Estimation Based on Aggregate Commodity Data

Ann F. Friedlaender and Richard H. Spady, "A Derived Demand Function for Freight Transportation," *Review of Economic and Statistics*, Vol. 16 (1980), pp. 432-441.

This article develops improved estimations of freight demand. One improvement is explicitly treating transportation as an input in the production process and using Sheppard's Lemma, deriving transportation demand functions from initial cost equations. The empirical work also takes into account the interdependence of rates and service characteristics. Freight demand equations are estimated using a cross-section of 96 threedigit Standard Transportation Commodity Code industries. This methodology can be used to derive estimates of modal spilt and effects of policy changes on the demand for rail and truck services.

Aggregate Mode Shift Models: Explanation of Traffic Shifts Among Modes Due to Productivity Changes

Martha B. Lawrence and Richard G. Sharp, "Freight Transportation Productivity in the 1980s: A Retrospective," *Journal of the Transportation Research Forum,* Vol. XXXII, No. 1, 1991, pp. 158-171.

Authors assess general issues relating to productivity growth in the transportation sector during the 1980s. Authors advocate use of the total factor productivity (TFP) techniques in order to improve comprehensiveness and eliminate biases from single factor productivity measures. Authors generally criticize a number of productivity studies because of an undue reliance on financial indicators as a substitute for physical productivity measures and inadequate controls for changes in output mix.

Perhaps the most relevant section for our purposes is one on productivity and traffic shifts between modes. The authors cite data on the continued loss of market share to motor carriers in the 1980s and its effects on overall productivity changes.

The authors also highlight the importance of service advantages of trucks arguing that trucks provide a fundamentally different type of service from rail. Trucks offer service ubiquity, freedom from sunk cost facility commitments, and adaptability to smaller units of shipment. Accordingly, mode choice studies must go beyond the traditional service characteristics of transit time and variation and rates in modeling shipper choice.

Aggregate and Disaggregate Freight Demand Models: Survey of Previous Efforts and Prospect of Combining Approaches

Clifford Winston, "The Demand for Freight Transportation: Models and Applications," *Transportation Research,* Vol. 17A, No. 6, (1983) pp. 419-427.

This review article classifies freight demand models as being aggregate (where the unit of observation is the aggregate share of a particular mode in a broad product and geographic market) or disaggregate (where the unit of observation is an individual shipper or shipment). While Winston argues that disaggregate models are more attractive from a theoretical viewpoint since they can be derived from cost-minimizing behavior by firms, he also notes that some of the more recent aggregate models have also been derived from firm cost-minimizing behavior and, therefore, have a stronger theoretical basis.

The Oum and Freidlaender and Spady models, estimated from aggregate data, might be more useful in the analysis of freight flows for policy analysis or practical prediction in the context of large, scale regional or national studies.

Two types of disaggregate freight demand models have been developed: behavioral and inventory. The behavioral models take the perspective of the physical distribution manager in making mode choice decisions to maximize utility with respect to expense and service. Typically, a random utility model is used with discrete choice estimation tools. Inventory-based models analyze freight demand from the perspective of an inventory manager in an attempt to integrate the mode choice and production decisions.

The article discusses a number of applications of freight demand models, including intermodal competition, regulatory analysis, and forecasting of freight flows. Most relevant for this project is the latter application. Previous attempts to forecast freight flows have used techniques such as input-output and regional flow models, but have not combined these techniques with a realistic freight demand model. It is Winston's opinion that the combination of a forecasting system with a realistic freight demand model imbedded into it could contribute significantly to the accuracy of freight flow forecasts.

Thomas L. Zlatoper and Ziona Austrian, "Freight Transportation Demand: A Survey of Recent Econometric Studies," *Transportation*, Vol. 16 (1989), pp. 27-46.

This paper surveys econometric studies of freight transportation demand published between the mid-1970s and the mid-1980s. It describes the variables, data sources, and estimation procedures utilized by the studies. In addition, it summarizes their statistical results. The studies included in this survey typically accounted for freight rates and service characteristics (e.g., transit time and reliability). Data sources often varied across the studies.

Based on the data they utilized, the surveyed studies are classified as either aggregate or disaggregate. The data in the aggregate studies consist of information on total flows by modes at the regional or national level, while the data in the disaggregate studies pertain to individual shipments. The earlier aggregate studies estimated linear logit models. It has been pointed out that when they are estimated on aggregate data, these models are subject to certain shortcomings. To avoid these shortcomings, more recent aggregate studies have estimated flexible forms such as translog functions. The disaggregate studies surveyed in this paper used either logit or probit models.

Statistical results often varied with the commodities analyzed, making it somewhat difficult to generalize the findings of the different studies. One finding common to several studies reviewed is that freight rates have a significant impact on shipment decisions. Certain theoretical and empirical limitations of the surveyed studies are discussed; and suggestions for future research in freight transport demand are offered.

B. Discrete Choice Models: Individual Shipper Selection Models

Mode-Split/Mode Choice Models: Discrete Individual Shipper Choice

F. R. Wilson, B. G. Bisson, and K. B. Kobia, "Factors That Determine Mode Choice in the Transportation of General Freight," *Transportation Research Record 1061*, 1986, pp. 25-31.

This study relies on data collected from a survey of manufacturers regarding their modal selection and shipment characteristics. It uses the survey data in a linear logit model to determine the variables that influence the selection of the various modes and the relationship between each mode and the explanatory variables. Shippers are asked to state their preferred shipping mode for their main product over their primary origin-destination link.

The modal choice explanatory variables are divided into the following categories: characteristics of the transportation system; characteristics of the shipment; characteristics of the carriers; and characteristics of the shipper. The model has quite a comprehensive set of considerations as explanatory models.

The model has most relevance for predicting how an individual shipper might select a particular model based on shipment characteristics as well as firm characteristics (such as firm size, volume of business). The model would not be appropriate if the researcher were attempting to look at overall shipment levels and model uses. However, the model does suggest that a number of quite detailed individual firm characteristics do influence the selection of mode.

Mode-Split/Mode Choice Model: Discrete Individual Shipper Choice

A.S. Narasimha Murthy and B. Ashtakala, "Modal Split Analysis Using Logit Models," *Journal of Transportation Engineering*, Vol. 113, No. 5, September 1987.

Extensive survey of over 7,000 shippers in Alberta, Canada used to develop a cross-classification table looking at modal split as a function of the following variables: shipment size; full load vs. less-than-full load; private or for-hire transportation; control over mode choice; and type of commodity.

This cross-classification table provides the input for a multi-way contingency analysis (logit analysis) specifying the relationship between each of the variables, by itself and interacting with the other variables, and mode split.

The coefficients developed in the model can be employed to predict modal shares under a variety of scenarios regarding each of the analysis variables. However, it should be noted that the model gives no consideration to modal rate or service comparisons. Thus, the model could not be used to analyze how modal shares would change based on relative rate and service changes in the various modes. This would be a serious drawback for many of the uses of the model contemplated by policy makers.

Saleh Ali and Yorgos J. Stephanedes, "Policy-Sensitive Disaggregate Techniques for Estimating Freight Highway and Rail Use," *Journal of the Transportation Research Forum*, Vol. XXV, No. 1, 1984, pp. 155-164.

The authors develop a mode split model based on data from Midwest grain elevators. One of the main variables included in the model was rate information. Truck rates were considered as a function of distance, while rail rates were considered as a function of shipment size and distance. The authors also included transit times for rail and truck and service time availability (i.e., the time between the equipment is ordered by the shipper and the time it is received at the grain elevator). Further, the authors include a measure of transit time variability in their model.

Results indicate that the freight rate and service availability time were the most significant determinants of modal decisions.

Vivien P. Jeffs and Peter J. Hills, "Determinants of Modal Choice in Freight Transport: A Case Study," *Transportation*, Vol. 17, 1990, pp. 29-47.

Authors surveyed a number of organizations with regard to the following variables which influence the modal choice at the firm level: customer-requirements; product characteristics; company structure/organization; government interventions; available transport facilities; and perceptions of the decision maker in the firm. The authors argue that it is the interactions and inter-relationships among these variables that influence the modal split. Thus, the relevant focus of modal split analysis should be on the firm and its characteristics.

The authors support their viewpoint with a survey of firms in England in the paper, printing, and publishing sector. They rely on factor analysis to show that many of the individual items discussed above interact to influence mode choice.

The main contribution of the paper is the viewpoint that modal choice is influenced by a large variety of characteristics of the firm, including ones that are individual firm-specific. For example, the urgency of delivery as well as the timing of delivery are factors that could be relevant in developing some inferences on the just-in-time trends that are becoming so important in our economy.

While showing that many of these firm-specific factors are important, this paper provides no explicit framework for entering these considerations into a modal choice model.

However, this methodology (i.e., survey shippers about their modal choices and influencing factors) could be employed to analyze the impact of future policy decisions and freight trends. For example, the impact of restricting truck access during peak hours could be analyzed through such an approach.

J. Pike, *Major Factors Influencing Modal Choice in the UK Freight Market*, Transport Operations Research Group, University of Newcastle upon Tyne, Department of Civil Engineering, December 1982, National Technical Information System.

The basic source of information for this study was information from ten companies who provided detailed data regarding their modal choice decision processes. In their study, the authors have uncovered a variety of modal rate and service characteristics that affected shipper choice. The authors conclude that the wide range of non-rate factors influencing modal choice decisions suggests that modal split models must be conducted at a disaggregate level.

The authors don't develop their own model, but discuss the importance of modal service characteristics in the decision process of the individual firm.

Mode Choice/Mode Split Considerations: Need to Include Shipment Size and Inventories in Discrete Shipper Selection Models

Y.S. Chiang, Paul O. Roberts, Jr. and M. Ben-Akiva, "Short-Run Freight-Demand Model: Joint Choice of Mode and Shipment Size," *Transportation Research Record*, No. 838, 1981, pp. 9-12.

This paper estimates a freight demand model that involves the choice of mode as well as the choice of shipment size. A disaggregated approach is used. The basic data employed in the model comes from the 1972 Commodity Transportation Survey. One innovation of the model is to include from an inventory theory elements of logistics costs, including capital carrying costs in storage and in transit, order costs, loss of value during transit and storage, and direct transportation charges. One result of the model is that shippers put a very high value on improved travel times.

Mode Choice Models: Discrete Individual Choice with Elimination of Choices Based on Attributes

W. Young, A.J. Richardson, K.W. Ogden, and A.L. Rattray, "Road and Rail Freight Mode Choice: Application of an Elimination-by-Aspects Model," *Transportation Research Record*, No. 838, 1981, pp. 38-44.

These authors challenge the notion of most mode choice models that each individual considers all alternatives, and each attribute that describes those alternatives, before making a choice. Rather, the authors argue, shippers may attempt to simplify the choice process by eliminating many alternatives and/or attributes from active consideration. Models that allow for the elimination of attributes, such as the Elimination-by-Aspects approach, are viewed as preferable.

One feature of the model is that it assumes that individuals search modal attributes in a sequential fashion, proceeding from those attributes considered most important through to those that are considered least important. As each attribute is considered, each alternative is compared to that attribute. If the alternative fails this test, (i.e., less that minimally acceptable), it is no longer considered. This process continues until only one alternative is left.

The Elimination-by-Aspects model considers nine modal attributes: transit time, reliability, equipment availability, frequency of service, freight rates, loss and damage, convenience of service times, and communication with the carrier. The model is calibrated for different shipper classes. Depending on the type of shipper, different sets of attributes are shown to have a significant impact on mode choice.

The model's most significant contribution is to show that different factors influence the mode choice of shippers of manufactured and non-manufactured goods. Models assuming that all attributes affect the choice of all shippers are inconsistent with this finding.

4. Network Assignment

Network Assignment Models for Freight Planning

Michael C. Bronzini, *Freight Transportation Energy Use*, prepared by CACI, Inc. - Federal for U.S. Department of Transportation, Transportation Systems Center, four volumes, July 1979.

This is one of a series of multimodal network models developed by CACI in the late 1970s. The models consist of node and link representations of rail, highway, waterway, and pipeline systems plus a set of intermodal links. Time and cost functions are associated with each node and each link. Mode and route choice for individual shipments or commodity flows are determined to minimize a commodity-specific function of time and cost. The commodity-specific values of time used in this function were adjusted to calibrate the model to base-year (1972) data. A comparison of the resulting values of time used to initial estimates based on commodity values indicates that significant difficulties were encountered in this calibration process.

Robert C. Bushnell, and Edward S. Pearsall, "Applications of a Freight Network Model to the Analysis of Competitive Situations," Proceedings, Transportation Research Forum, Vol. 22, 1981, pp. 379-393.

The Integrated Transportation Network Model contains representations of the highway, rail, and waterway networks, as well as costs and time delays resulting from mode transfers, operations through railroad yards, and transfers between rail carriers. This model was developed in the late 1970s under contracts with the U.S. Departments of Transportation and Energy and the State of Michigan. However, it was never developed as fully as the CACI model described above. An updated version of the rail component of this model with 1989 routings of doublestack trains and the location of container loading facilities was used as the first stage of a two-stage model of container import and export traffic recently developed by Jack Faucett Associates (*The U.S. Export/Import Containerized Freight Model*, 1990).

Teodor Crainic, "Operations Research Models of Intercity Freight Transportation: The Current State and Future Research Issues," *Logistics and Transportation Review*, Vol 23, No. 2 (1987), pp. 189-206.

The author argues that it is now possible to build comprehensive interactive graphic-planning systems that run on micro-computers and thus put impressively powerful computational and planning means within easy financial reach of practically every size of organization (carrier, shipper, etc) involved in the transportation system.

The author provides a classification of how network models can be used according to three alternative planning horizons: strategic or long-term planning, which may include decisions such as facility location and physical network design and upgrading; tactical or medium-range planning, which would involve service and routing decisions; and operational or short-term planning, including scheduling and routing of vehicles.

The main focus of this article is on tactical level issues. However, the decisions faced by state transportation departments would most often include the strategic planning variety.

Network Assignment Models for Freight Planning: Rail Models

Teodor Crainic, Michael Florian, and Jose-Eugenio Leal, "A Model for the Strategic Planning of National Freight Transportation by Rail," *Transportation Science*, Vol. 24, No. 1, February 1990, pp. 1-24.

This article describes in more detail the rail portion of the multimodal, multiproduct network model done for Brazil. It provides a review of network models for rail transportation, updating earlier reviews by Assad (1980), Crainic (1987), and Freisz (1983).

It provides an illustration of how the model can be used to assess the impact of a new rail construction project on current and projected freight flows in a Brazilian rail corridor.

Jerome M. Lutin and Alain L. Kornhauser, "Development of a Differential Route Share Model for Railroad Freight Traffic," 1980.

This article describes the railroad network model developed by Kornhauser and used over a number of years through ALK & Associates. The model provides a comprehensive replication of the US railroad network. Traffic data were obtained from the ICC's waybill sample. Regression models were used to predict how traffic would flow across alternative rail routings. The main variables which predict traffic flow are: impedance, which includes track condition, total distance, and originating carrier length of haul; total route length; and junction frequency. This model has been used in a number of policy applications, including traffic diversion effects from railroad mergers.

Network Assignment Models: Review and Ability to Incorporate Behavioral Intentions of Individual Shippers

Terry L. Friesz, Roger Tobin, and Patrick Harker, "Predictive Intercity Freight Network Models: The State of the Art," *Transportation Research*, Series A, Vol. 17A, pp. 409-417 (1983).

This is a review article of network models. Table 1 reviews six major network models (Harvard-Brookings, CACI, Peterson, Lansdowne, Princeton, Penn/ANL) on sixteen criteria (multiple modes; multiple commodities; sequential loading of commodities; simultaneous loading of commodities; congestion; elastic transportation demand; explicit shippers; explicit carriers; sequential shipper and carrier submodels; simultaneous shipper and carrier submodels; sequential macroeconomic and network models; simultaneous macroeconomic and network models; nonmonotonic functions; explicit backhauling; blocking strategy; and fleet constraints). The article includes a section on recent advances and suggestions for future research, including more attention to behavior intentions for shippers and carriers.

■ B.3 The Direct Approach: Micro and Facility Related Planning

Use of Input-Output Models to Assess Economic Impact of Investments

B. Stevens, *Basic Regional Input-Output for Transportation Impact Analysis,* NCHRP Project 8-15A, Regional Science Research Institute, July 1982.

This ambitious project is an effort to provide state highway and transportation planners with hands-on input-output analysis tools. Input-output (IO) models can be used in a number of planning activities. In a structural approach to freight forecasting, such models can be used to determine flows of goods from various origins to destinations. The emphasis in this report is on the use of IO models for analyzing economic impacts of state highway investment and other similar investment. Such investment generates employment from construction activity, and can also result in more travel, new businesses locating in the area and the like. Estimating the cumulative economic impact, including these multiplier effects, is the subject of this report. Although not specifically in the purview of freight demand forecasting, this was an area cited by transportation planners in Iowa as an important tool in analyzing proposed transportation investment, to be used in conjunction with forecasting tools in determining where investment dollars might best be spent.

Use of Simple Time-Series Forecasts to Predict Trends in Freight Flows of Particular Industry Sectors

V. Eusebio and S. Rindom, *Grain Transportation Service Demand Projections for Kansas: 1995 and Beyond,* Kansas Department of Transportation, July 1990.

This study provides an example of state use of direct forecasting techniques. The first stage of the study projects grain production and livestock and poultry populations for the state. Then time series methods, specifically exponential smoothing and an autoregressive component from the SAS statistical package, are used to produce forecasts. Finally, with production data forecast, transportation is assumed at 95% of production. This study suggests that simple, time series forecasting techniques, now available through standard statistical packages, can be well utilized by state planners without the aid of outside consultants. Also, it points to the state-specific type of data sometimes used in forecasting studies, suggesting limitations to our ability to provide all-encompassing forecasting data.