FINAL REPORT

A METHODOLOGY FOR STATEWIDE INTERMODAL FREIGHT TRANSPORTATION PLANNING

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ABSTRACT

The researchers developed a methodology for statewide freight transportation planning that focuses on identifying and prioritizing infrastructure needs to improve the intermodal freight transportation system. It is designed to provide the framework for state departments of transportation and metropolitan planning organizations to meet the freight transportation planning requirements as mandated first by the Intermodal Surface Transportation Efficiency Act of 1991 and then by The Transportation Equity Act for the 21st Century.

The researchers accomplished this by interpreting the results of a literature search on the legislation, participant roles, and analytical methodologies to formulate the steps of the method and demonstrating how each step is performed. The process is based on the interaction between inputs from stakeholders and a technical analysis that provide decision support information. A case study demonstrates how the technical tasks for the system inventory and data forecasting are accomplished. The study shows that a standard but flexible freight planning methodology can help remove impediments to efficient goods transportation. Future developments such as geographic information system data, improved freight flow data, and established system inventories are shown to facilitate the recommended process.

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INTRODUCTION

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) emphasized the responsibility of states to provide for the efficient movement of people and goods.[1] As a result of Section 1025 of the legislation, states must include a freight component in their transportation plans. States must also explicitly consider 23 factors listed in the planning regulations entitled *The Final Rules for Statewide Planning: Metropolitan Planning* when developing their statewide transportation plans. Two of these 23 factors deal explicitly with freight transportation:

1. international border crossings and access to ports, airports, intermodal transportation facilities, and major freight distribution routes

2. methods to enhance the efficient movement of commercial motor vehicles.

Further ISTEA guidelines state that plans shall "be intermodal (including consideration and provision as applicable, of elements and connection of and between rail, commercial vehicle, waterway, and aviation facilities, particularly with respect to statewide intercity travel) and statewide in scope in order to facilitate the efficient movement of people and goods."[2]

Virginia has recognized these planning responsibilities in its strategic planning process report, *Virginia Connections.*[3] Intermodalism and freight are included as two of the seven guiding principles outlined in the report. In true ISTEA fashion, the document states that "transportation policies and planning will emphasize the movement of people and goods from origin to destination rather than mode-specific travel." The document emphasizes the importance of freight transportation planning to Virginia and is summarized by the statement: "For Virginia to remain competitive in attracting new and expanding business interests, and continuing economic growth, its transportation network must facilitate the rapid and economical movement of raw materials and finished products." [3] In addition to the economic benefits, improved intermodal freight transportation promises positive air quality and environmental impacts, more efficient use of existing transportation infrastructure, and increased partnerships between the public and private sectors.

State departments of transportation (DOTs), including Virginia's, have traditionally focused on planning their transportation infrastructure for the movement of people, with little or no consideration to the movement of goods. To bring freight transportation planning in Virginia to the sophisticated level sought by ISTEA, a set of consistent and standard procedures is needed. A methodology for intermodal freight transportation planning that can be used by state and local metropolitan planning organizations (MPOs) needs to be developed.

PURPOSE AND SCOPE

The purpose of this project was to develop a methodology that can be used by the Virginia Department of Transportation's (VDOT) Transportation Planning Division (TPD) and the Virginia Department of Rail and Public Transportation to plan the infrastructure to support efficient intermodal freight transportation in Virginia.

The methodology needed to be flexible, so that it can adjust and evolve to changes in the freight planning arena, such as the availability of more detailed goods movement data and the development of more sophisticated freight forecasting methods.

Only goods movements that have Virginia as an origin and/or destination were considered in this project. The methodology needed to be multimodal and intermodal, i.e., address goods moved by all modes and goods moved by more than one mode. The intermodal aspect requires that the process address the modal transfer of goods. The planning process was to be directed at the public sector infrastructure that supports freight transportation by motor carrier, rail, water, pipeline, and air. Motor carriers, or trucks, is the mode most dependent on state infrastructure because of their heavy use of state highways. Other modes, such as rail, are less dependent on the state because they use their own privately owned facilities. Nevertheless, in an intermodal world, these modes often interact with state infrastructure (railroad crossings, transfer facilities, landside access), and, therefore, coordination with privately owned infrastructure had to be included in a statewide intermodal freight transportation planning methodology.

METHODS

Conduct a Literature Review. A computerized literature search was performed using Transportation Research Information Services (TRIS). The review focused on federal requirements for statewide freight planning, general planning concepts for freight and passenger transportation, freight planning efforts of other states, and freight planning in Virginia. Information on freight planning in other states was scarce, so the few state DOTs that were identified as having statewide freight planning efforts were solicited for further details. Telephone and email interviews were conducted, and additional documentation of the agency's freight planning was collected along with information regarding intermodal management systems (IMS).

Develop the Statewide Intermodal Freight Transportation Planning Methodology. A framework for the methodology was developed, and tailored to the needs of Virginia, using the experiences of other states and MPOs. Guidelines for the developed freight planning process were also generated, which included the identification of appropriate planning tools and potential sources of data. In developing these guidelines, particular attention was given to freight-specific planning Steps and tools that the passenger-planning professional might not be familiar with. The freight planning methodology and guidelines were developed in such a manner that they could evolve and improve as more sophisticated freight planning tools and more accurate data became available.

Conduct a Case Study. A case study was used to demonstrate how the developed methodology can be used to address a freight planning issue in Virginia. The case study provided insight on the Steps to be taken and how deficiencies in data can be overcome.

RESULTS

Literature Review

Federal Legislation

The necessity for a statewide freight transportation planning process first became a federal requirement with the passage of the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991.[1] Section 1025 of the legislation stipulates that a state's planning process must be continuous and include freight by recognizing "access to major traffic generators such as ports, airports, intermodal transportation facilities, and major freight distribution routes." Specific sections of the act that are relevant to statewide freight transportation planning are the Final Rules for Statewide Planning: Metropolitan Planning[2] and the Management and Monitoring Systems.[4]

General Planning Concepts for Freight and Passenger Transportation

The literature includes several sources relating to general freight planning concepts. The majority of the references discuss the passenger planning process, but recent freight planning concepts were identified. Some, such as the systems approach to planning and the use of performance measures, apply to both passenger and freight transportation.

The Systems Analysis Approach to Transportation Planning

The traditional transportation planning process uses a systems analysis approach. This involves setting goals at an early stage in the process and evaluating candidate solutions with relation to these goals. This allows for a top-down approach, where the process moves from the general, that is, setting goals and objectives, to the specific, that is, developing and evaluating alternative solutions.[5]

The systems approach allows the transportation planning process to be rational, that is, based on carefully gathered evidence weighed and analyzed using a logical procedure. It also leads to decisions that are objective, that is, fair, balanced, unbiased, and free from personal whim.[5]

The systems approach was used by the Federal Highway Administration (FHWA) in its planning process for intermodal transfer facilities.[6] The are seven steps to the process:

1. *Identify and define the problem*, i.e., problems related to access of intermodal transfer facilities, such as congestion and inadequate bridge clearances.

2. *Establish appropriate performance measures*:

    - *physical measures:* connections to transportation systems, other intermodal facilities, and principal markets; number of at-grade rail crossings; tunnel and bridge clearances

    - *operational measures:* level of service, environmental impacts

    - *user measures:* total travel and delay time and cost, freedom of scheduling, mode choice, route choice.

3. C*ollect data and define present conditions*, i.e., data to assist the understanding of the facility operation, support performance measures, and support forecasting efforts.

4. *Forecast and define future conditions*, either by projections of historic rates or market and capacity studies to determine projected yearly throughput, which can be converted to daily trips through an understanding of terminal operating characteristics.

5. *Develop and analyze alternative improvements*. Alternatives include the introduction of a new intermodal transfer facility, system improvements such as new or improved access roads/rail lines and grade separations, system management such as route definition and exclusive use facilities, demand management to promote mode or route shifts, and consolidation of access routes. The alternatives should be evaluated with respect to previously established performance measures, construction and operating cost, funding availability, environmental, socioeconomic and land use impacts, feasibility, and local/regional factors.

6. *Implement improvements*. This step consists of completing engineering design and property acquisition, ensuring inclusion in the Transportation Improvement Program and the Statewide Transportation Improvement Program, reviewing funding

availability and conformity with Clean Air Act and Clean Water Act, and obtaining local and regional project approvals.

7. *Monitor effectiveness of improvements*. Evaluate the actual performance of the system with relation to the established performance measures.

Performance-Based Planning Processes

ISTEA requires that states implement a performance-based planning process. Performance measures are yardsticks that can be used for objective monitoring and evaluation of existing transportation systems as well as assessment of improvement options and allocation of funding. In the ISTEA era, appropriate performance measures treat the transportation system as an intermodal system that provides mobility for both people and goods. Performance measures are also becoming more user-oriented; that is, factors such as travel time and cost are considered more useful than level of service.[7]

Figure 1 shows the framework for a performance-based planning process as suggested by FHWA in *The Use of Intermodal Performance Measures by State Departments of Transportation.*[8] Of particular note is that the task of defining performance measures appears early in the process, immediately following the definition of goals and objectives. This places great importance in the performance measures because they will influence the overall process in a manner similar to goals and objectives. This document recommends that performance measures be derived from goals and objectives so that the effectiveness of proposed actions can be measured in terms of those goals. Previously, evaluation indicators would be pushed to the end of the process and would often be seen as an afterthought.

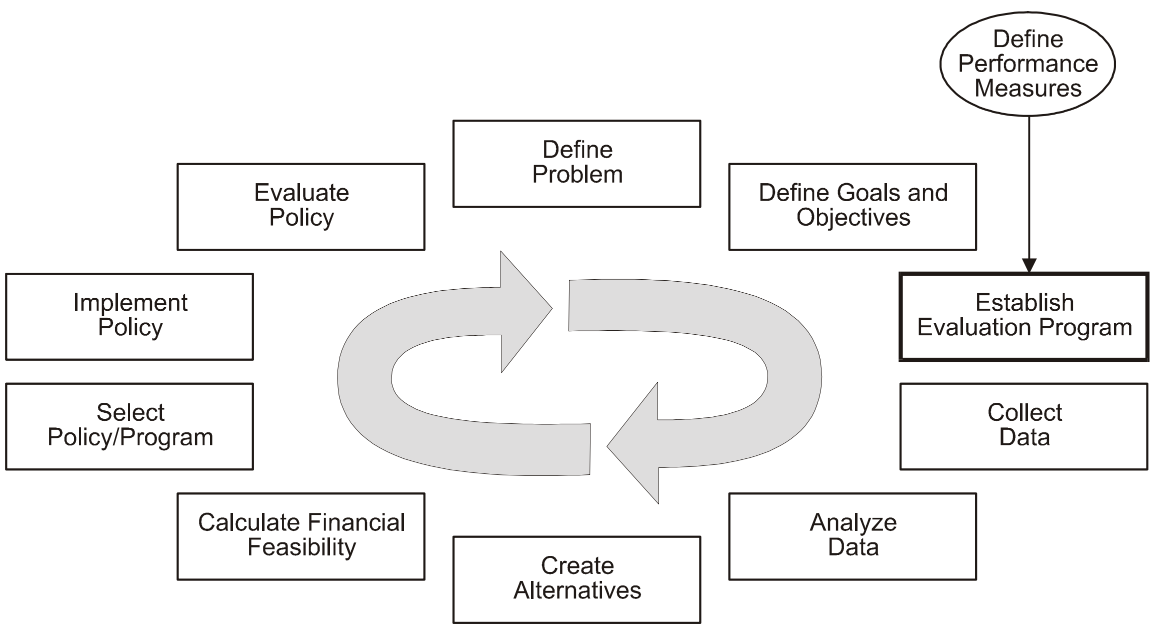

Figure 1. Performance-Based Planning[8]

By defining performance measures before data are collected, data gathering requirements can be reduced. This is because only data that relate to the specific performance measures or goals and objectives should be collected.[9]

Freight Performance Measures Recommended in the Literature

As part of *The Use of Intermodal Performance Measures by State Departments of Transportation*,[8] a survey was taken of 15 state DOTs to determine which goals and performance measures are being used for intermodal freight movement. The survey identified 21 goals (including one called "other") and 211 associated performance measures for freight transportation. The use of performance measures for each of the 6 most common goals is shown in Table 1. Freight performance measures used by specific states are discussed later in this document.

Table 1: Use of Performance Measures for Six Most Common Freight Movement Goals Identified by Survey of State DOTs[8]

Freight Movement Goal	Performance Measure
Accessibility of Intermodal Facilities	External Measures (outside intermodal facility): • Level of service • Actual conditions of transportation route • Bridge restrictions Internal Measures (within intermodal facility): • Queuing of vehicles • Turning radius into facility • Deficiencies of intermodal facility
Availability of Intermodal Facilities	• Volume to capacity ratios • Railroad track capacity • Storage capacity
Cost and Economic Efficiency	• Cost per ton-mile by mode • Revenue costs • Expenditures
Safe Intermodal Choices	• Number of crashes • Cost of crashes • Number of fatalities
Connectivity Between Modes	• Number of facilities • Delay of trucks at facilities • Travel times
Time	• Total transfer time • Freight transfer time between modes • Average travel time

Private Sector Participation in Statewide Freight Planning

Public planning agencies have found that a core group of goods movement stakeholders can successfully provide input to freight planning. This can be considered the equivalent of citizen input in the passenger transportation planning process. This core group is typically known as a freight advisory council (FAC). The establishment of a FAC is recommended and discussed in *Public-Private Freight Planning Guidelines*[10] that was derived from research conducted for FHWA by the American Trucking Association, the Pennsylvania State University Center for Logistics Research, and the Pennsylvania Transportation Institute. The guidelines are based on real-world public-private freight planning efforts of MPOs, including the Puget Sound Regional Council, Metropolitan Transportation Commission (San Francisco, Oakland, and San Jose), Capital District Transportation Committee (upstate New York), Toledo Metropolitan Area Council of Governments, and Chicago Area Transportation Study. The study found that "planning organizations across the country are tapping the professional knowledge and resources of the private sector to assist in transportation planning efforts."[10]

The importance of FACs is also stressed in *Planning and Managing Intermodal Transportation Systems: A Guide to ISTEA Requirements*, which states "The Freight Advisory Council is not just a formality, but a necessity. It is *the* most important *networking resource*. Agencies can find out what issues are important to private sector users, define data needs on that basis, and initiate mechanisms for sharing private sector freight intermodal information."[9]

FACs

The FHWA's *Public-Private Freight Planning Guidelines* recommends that a region's major freight transportation players be included in the FAC.[10] These include representatives from local planning agencies, port authorities, major carriers (railroads and trucking companies), package delivery companies (UPS, Federal Express), and the region's major shippers and industries. Participation by the principal members of the freight community increases the credibility of the FAC and will attract other parties to participate. The document recommends that all modes be represented and that at least two thirds of the participants be from the private sector. It can also be beneficial to include associations such as a chamber of commerce or economic development agency. [10]

Cambridge Systematics' *Freight Matters: Trucking Industry Guide to Freight and Intermodal Planning Under ISTEA* provides guidelines to the private sector trucking industry on how to become involved in public sector planning of goods movement infrastructure.[11] The document stresses an ISTEA approach, that is, forming an industry advisory committee of shippers, receivers, and motor carriers to ensure that the trucking industry's voice is heard.

Public-Private Freight Planning Guidelines states that establishing goals for freight planning efforts driven by the FAC is important because such goals guide the FAC's activities.[10] Typical goals of FACs include fulfilling ISTEA requirements, establishing communications between the freight community and planning agencies, assisting with economic development efforts, addressing specific regional problems, and generating inputs for planning or other analytic processes.[10]

From the perspective of the private sector, *Freight Matters* stresses being proactive from an early stage in the planning process.[11] The document observes that private sector goods movement providers are in the best position to define the industry's needs, identify and rank freight bottlenecks, and suggest reasonable solutions to problems and should communicate this knowledge to the public sector planning agencies. It also recommends that the trucking industry provide technical guidance to freight planning efforts of states and MPOs in areas such as logistics patterns by industry, commodity forecasts and forecasting techniques, truck route standards, and model procedures for conducting cost/benefit analyses.[11]

From their review of planning agencies across the country, *Public-Private Freight Planning Guidelines* found the following activities to be common of FACs:

- *Generating lists of short-term improvements.* This involves providing information on bottlenecks in the freight network that can be easily remedied and brainstorming for cost-effective efforts that can provide immediate benefits.

- *Conducting/assisting in large-scale corridor studies*. This involves larger, more complex projects on a corridor level to address bottlenecks, such as raising bridge heights to accommodate double-stack trains.

- *Working on specific projects*. These groups are sometimes referred to as task forces and are assembled to address specific problems, such as reducing delays and congestion at rail crossings and promoting economic development along a rail corridors.

- *Collecting data or assisting in modeling efforts*. Private sector participants in FACs might become more willing to provide or assist in the collection of data as they develop trust that the data will not be misused and that unnecessary data will not be collected. [10]

To ensure that private sector participation in FACs does not dwindle, *Public-Private Freight Planning Guidelines* recommends the following strategies to keep interest and attendance high:

- *Time management*. Representatives from private companies on the FAC will respond more favorably to well-planned meetings that are convenient for them to attend. FAC meetings should adhere to a preapproved agenda and be held at locations that are convenient for most participants.

- *Education/communication*. The public sector participants should be patient in educating the private sector about transportation planning processes, policies, proposals, acronyms, and so on. In turn, the private sector should make efforts to inform the public sector on their day-to-day operations and the logistical problems they face. As well as educating each other, the public and private sector will benefit by improving citizens' understanding of the importance of freight.

- *Short-term results*. One of the major problems facing public-private partnerships in freight transportation planning is varying time frames. Private firms may consider *long-term* to mean 6 to 12 months, whereas planning agencies often plan in 20-year time frames. In the private sector, "time is money," and representatives from private companies will expect to see immediate dividends from their time spent participating on a FAC. To maintain the interest and participation of the private sector, FACs should attempt to generate "quick start" projects. These provide the FAC with a positive track record that can be noted as tangible results by the private sector participants, thus increasing the likelihood they will continue to participate. Examples of quick start projects are generating lists of bottlenecks and generating lists of easily implemented and cost-effective improvements such as altering signal timing, improving curbside management, and facilitating overnight truck and container parking.

- *Review of focus/purpose*. A systematic and intermittent review of the FAC's goals will provide continuing direction and purpose to the group.[10]

Some situations should be avoided to maintain private participation in FACs.[10] One circumstance that could be particularly damaging is if the activities and actions are seen to favor one mode or industry . It is important that all participants be considered and treated fairly and equally; otherwise, the members could become "splintered" and participation could dwindle. Controversial issues that could favor one mode or industry should be handled delicately, with local trade associations working with the affected companies. The FAC should strive to address matters that improve freight movement in the state as a whole, rather than any particular group.

Data for Freight Transportation Planning

Freight data are necessary to understand current freight transportation and plan for future changes. Some major obstacles to freight planning are that goods movement data are not widely available, are scattered throughout the private sector, and are proprietary. Individual shippers and carriers have the information on their own goods movement, but they are often unwilling to divulge these data because they could provide rival businesses a competitive advantage.[12]

The two major uses of freight data are in the use of freight performance measures and freight forecasting methods, which are discussed later in more detail.

Data Requirements of Freight Performance Measures

Data required for freight planning are primarily in the form of characteristics of freight transportation facilities. The characteristics may be physical, such as number of berths; operational, such as travel speed; or statistical, such as number of crashes per year.

Data collection efforts can be expensive and time-consuming, particularly in freight transportation. For this reason, it is often desirable to simplify data collection efforts as much as possible. *Planning and Managing Intermodal Transportation Systems: A Guide to ISTEA Requirements* recommends collecting issue-based data to support the use of performance measures in freight planning.[9] This allows data collection to be focused on the most important "hot button" projects to alleviate the most pressing bottlenecks. By prioritizing within particular issue areas, data search efforts are more efficient and can provide an indication of how the data will ultimately be used. Another advantage of issue-based data collection is that it minimizes the possibility that important transportation issues are dictated by data availability rather than vice versa. This could falsely eliminate important issues from consideration, just because data are not readily available.

Management and Monitoring System also encourages issues-based data collection by stating that "states and local agencies are strongly encouraged to identify their intermodal transportation issues and determine the type and level of data that are necessary to address these issues."[4]

To minimize the amount of expensive data collection, many planning agencies have decided to develop freight performance measures that rely on the use of existing or available data. This was the procedure used by the MPO of Hampton Roads, Virginia, when collecting data for its IMS, as discussed later in this document.[13]

Data Requirements for Freight Forecasting Methods

The freight forecasting methods previously discussed have different data requirements, depending on their complexity and level of detail. In general, forecasting methods that attempt to be the most comprehensive and provide results to the greatest level of detail are the most data intensive and also the least likely to be feasible. Some of the types of data, according to Maze, required for freight modeling are:

- *economic base data*, attributes, production rates, and consumption rates by commodity
- *transportation network data*, physical and operational characteristics of the freight transportation system
- *past traffic flow data*, to calibrate models, past commodity flows, mode relationships, and model performance can be used.[14]

The authors of *Characteristics and Changes in Freight Transportation Demand* found the structural approach to freight modeling to be particularly data intensive. To add to this problem, the data sources vary for each component of the process, and much of the data that are available are at the national level and require disaggregation.[15] Reaggregation of the data may be necessary before publication such that no single shipper can be identified.

Freight Data Sources

Although freight data are relatively rare, there are some existing sources. However, most of the sources are aggregated and based on samples that provide questionable accuracy.

There are two categories of freight data, primary and secondary. Primary data sources include all collection efforts that are specific to a particular project or study. They include surveys to provide specific shipment information, such as origin/destination and mode, and interviews with shipping firms. Secondary data are existing databases that can be used to evaluate intermodal transportation.[16] These include widely available databases such as the 1993 Commodity Flow Survey,[17] which provides freight flow data by commodity and mode at the state-to-state level, and privately owned databases, such as Reebie Associates' TRANSEARCH database. The TRANSEARCH database is developed by disaggregating national and state level freight flow, manufacturing, employment, and industry data to obtain estimates of goods movement flows by commodity and mode at substate levels.

A complete list of data sources can be found in the Bureau of Transportation Statistics' *Directory of Transportation Data Sources*.[18] This publication provides a comprehensive inventory of transportation data sources in the Department of Transportation, other federal government agencies, U.S. private transportation organizations, and Canadian and Mexican government agencies. The data sources are listed by agency and cross referenced in the index alphabetically and by mode.

A summary of goods movement data for Virginia is available in *Freight Transportation in Virginia; Selected Data From Federal Sources*, which is a compilation of the available federal sources for statewide goods movement from Virginia's perspective.[20] Some of the sources it includes are the 1993 Commodity Flow Survey, Rail Waybill Data from 1988 to 1992, 1994 United States Waterway Data, and the 1992 Truck Inventory and Use Survey.

Freight Forecasting Models

Most public sector research has been devoted to understanding passenger transportation demand. As a result, techniques and models have been developed and used to forecast passenger demand, and state MPOs have gained significant experience in this area. Passenger forecasting models usually contain the steps of trip generation, trip distribution, mode split, and network assignment.[20] There are, however, significant inherent differences between passenger and freight transportation, such as:

- *Units of measure*. Number of vehicles is the unit for passenger transportation, and they are relatively easy to count. Freight activity may also be measured by number of vehicles, but commodity measures such as volume and weight are also used.

- *Value of time*. Although the value placed on travel and waiting time can vary for different passengers, the differences are small compared to those that can exist for different commodities of freight, for example, coal and cut flowers. Time differences by mode are also more significant for freight.

- *Loading and unloading*. Passengers can generally enter and exit vehicles and change modes without assistance, but freight requires extensive facilities and equipment that are specialized for different commodities.

- *Type of vehicles*. Freight vehicles include general purpose, designed to carry various commodities, or specific purpose, designed to carry refrigerated goods, liquids, dry bulk, and so on.

- *Number of decision makers*. In passenger transportation, decisions are made by numerous individuals, each of whom contributes only a small amount to overall demand. In freight transportation, a smaller number of shippers, receivers, agents, and carriers make decisions, any one of which can significantly alter overall demand.[20]

These differences prevent the existing models for forecasting passenger demand from being applied to forecast freight demand.

Types of Freight Forecasting Models

NCHRP Report 388, *A Guidebook for Forecasting Freight Transportation Demand,* reviews existing freight demand forecasting studies and categorizes them into structural and direct approaches.[20]

The Structural Approach. The structural approach to forecasting freight transportation demand is patterned after the four-step urban planning process (trip generation, trip distribution, mode choice, route assignment). It recognizes that freight demand is derived from economic activity and molded by intermodal and intramodal competitive forces and government actions. It involves comprehensive interrelationships among 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.

An example of the structural approach is NCHRP Report 260, *Application of Freight Demand Forecasting Techniques*.[21] This 1983 study presents a methodology consisting of three steps: freight generation and distribution, mode choice; and traffic/route assignment. The methodology is flexible to adjust for various degrees of data availability.

The first step of freight traffic generation and distribution involves estimating current volumes of freight traffic between origins and destinations. A base case commodity flow matrix is developed as a basis for making projected matrices. The commodity flow matrix can be produced using data-based or simulation approaches. The data-based option involves the use of existing commodity flow data, which may need to be disaggregated to the appropriate level, to estimate freight generation and distribution. The simulation technique requires the application of unit shipments and receipts (from industry production and consumption data) and derived distribution patterns. Future years can be projected directly from the base year, or production and consumption rates for individual commodities can be projected. A third option is to forecast macroeconomic indicators and adjust the base year commodity flow matrices accordingly.

The second step, mode choice, can also be accomplished in several ways. One method is to use cost and rate comparisons as the basis for splitting the traffic amongst modes. Another option is to compare modes from the perspective of shipper logistics, which recognizes that both cost and service are important factors in mode choice.

The third step of traffic/route assignment involves changing commodity flows to vehicle flows that can be allocated to the transportation system. Existing computer-based highway assignment techniques can be applied with little modification, particularly for the truck mode. The computer program selects the minimum impedance path between zones and assigns vehicles to the selected route. Manual or simplified computer-based techniques can be used for the rail and water modes, since these networks are fairly simple and route assignment is easy to predict. The use of computers allows a systematic accounting of volumes by segment and the calculation of distance or traffic related cost. Traffic assignment is necessary only if the planning application being used requires analysis of specific segments of the transportation network.[21]

Another example of the structured approach to forecasting freight demand is the *Quick Response Freight Manual*.[22] This methodology for predicting goods movement by the truck mode concentrates on data already available, provides default values for use in estimating and forecasting freight movements in the absence of extensive research, and provides a compendium of public and private data sources that can be used to customize models. A structured methodology is developed similar to that provided in NCHRP Report 260. The mode choice step is not included, since the methodology is for the truck mode only.

The Direct Approach. The direct approach to forecasting freight demand ignores, to some degree, some of the interrelationships analyzed in the fully structured model. It can be considered a simplification of the structured approach in that it usually addresses a specific aspect or component of goods movement rather than estimating the entire freight demand on the transportation system.

Maze of the Iowa Transportation Center is an advocate of the direct approach to freight forecasting in that he believes in treating commodities uniquely.[14] He states that "existing passenger travel demand models cannot be readily adapted to incorporate freight. Freight consists of different commodities, and the factors influencing their transportation patterns are inherently more complex than the variables affecting passenger transportation" and "not all modes are practical for all commodities." Maze goes on to explain that focusing freight planning efforts on major commodities for a region allows the consideration of mode-specific characteristics. Typically, the type of commodity, its volume, and time constraints will dictate which mode is used.

An example of the direct approach is explained in *Grain Transportation Service Demand Projections for Kansas: 1995 and Beyond*.[20] This 1990 study produces forecasts of grain production and livestock and poultry populations using time series methods such as exponential smoothing and an autoregressive component from the SAS (Statistical Analysis Software) package.

The direct approach is also documented in NCHRP Report 388.[20] This study concluded that forecasting multimodal freight demand is too complex to be accomplished by a single comprehensive model. Models developed to evaluate alternatives for new freight facilities would require location-specific data, without which a generic computerized model could not perform. Instead of developing such a model, the researchers decided to develop flexible procedures appropriate for a wide variety of applications. To forecast future freight demand for existing facilities, NCHRP Report 388 suggests using economic indicator variables or statistical techniques, such as regression analysis, univariate time-series techniques, and structural econometric time-series approaches. For the planning of proposed new freight facilities, without the benefit of a past usage record, the document recommends a procedure of including the following tasks:

1. *Identify the potential freight market*. This includes identifying competing facilities from which traffic is expected to be drawn and identifying types of commodities and modes of interest.

2. *Forecast changes in the market*. Economic indicator variables or statistical procedures can be used to estimate the changes expected during the forecast period.

3. *Estimate the new facilities' market share*. This includes route diversion, modal diversion, and induced demand.

4. *Evaluate the effects of alternative futures*. This step represents a defense against possible inaccuracies in the forecasts. A particular concern is that one or more shippers uses the facility considerably less than was predicted.

The document also discusses freight policy analysis and introduces methods to analyze the impact of government policies, such as taxes, size and weight restrictions, trade agreements, and truck safety programs, on freight demand.[20]

Other Concepts in Forecasting Freight Transportation Demand

A research team at Iowa State University's Center for Transportation Research and Education developed a freight forecasting method as part of their *Freight Planning Typology*.[23]

This approach forecasts freight for one industry or economic sector at a time. The justification for this "layered" approach is that just a few commodities usually comprise the majority of goods movement for most states or regions. By addressing each of these industries individually, planners can address economic development and the impact of infrastructure improvements. Since congestion and system capacity are generally not critical issues to freight planning, it is not necessary to analyze the entire range of goods movement at the same time.

The layered approach simplifies freight forecasting efforts because it is less data intensive, and specific industry sectors are likely to have similar transportation requirements.

The freight planning typology categorizes freight transportation problems by issue, mode, and commodity. By defining the specific problem in this way, it is easier to select the appropriate analysis tools and methodologies. The typology framework is:

1. *Identify issues*. Consultation with the Iowa DOT resulted in the division of freight issues or potential changes in transportation services, product demand, and product supply. A partial list of these is shown in Table 2.

Table 2: Partial List of Potential Changes Involving Freight Transportation Developed in Iowa's *Freight Planning Typology* [23]

Category	Potential Changes
Changes in Transportation Services	Transportation Infrastructure • Alter major corridors • Increase or decrease in congestion • Expansion, decline, abandonment of intermodal facility • Cost of providing transportation services • Infrastructure condition Transportation Industry • Mergers • Increased competition • Operations of transportation suppliers • Increased use of technology • International agreements Transportation Policy • Taxes/fees (toll roads, registration fees, fuel tax) • Regulation (vehicle weights, entry/exit barriers, rate and safety regulations) • Subsidies
Changes in Product Demand	Marketplace: • Changes in product price • Logistics operations (e.g., Just in Time) Policy: • International agreements affecting product demand and regulations that affect product demand
Changes in Product Supply	Marketplace: • Changes in locations of input suppliers • Industry changes that affect product suppliers (e.g., mergers) • Suppliers' input costs and market prices Policy: • International agreements • Land use regulations (zoning, growth investment)

2. *Identify modes*. The study categorized modes as truck, rail, air, water, and multimodal. Some commodities are dominated by a particular mode; for example, in

Iowa, meat products are primarily moved by truck. This narrows the scope of the planning effort.

3. *Identify commodity layers*. The industries generating the majority of the freight traffic in the region are identified. In Iowa, the primary commodities by total tonnage are grain, meat products, and farm machinery.

4. *Identify analytical tools and assess data needs*. The appropriate freight transportation analysis tools should be identified for the specific issue, mode, and commodity. Some of the more sophisticated tools are traffic assignment models, statistical procedures, input-output analyses, and econometric models. Simpler, more qualitative methods available to planners are spreadsheets, matrices, thematic maps, surveys, and focus groups. In a case study to identify important trucking routes for meat products and farm machinery in Iowa, MapInfo, a desktop GIS program, and Tranplan, a popular travel demand modeling package, were used.

5. *Identify data and develop the model*. Data collection efforts may be necessary to supplement currently available data. Data sources may require manipulation, such as aggregation or disaggregation into a form of consistent geographic area and time period. In the Iowa case study, Reebie Associates' TRANSEARCH data were used. The TRANSEARCH data were disaggregated from Bureau of Economic Analysis (BEA) level to county level freight flows that are more appropriate for statewide planning. This was accomplished for meat products using industry employment data to proportion origins and county population to proportion destinations. For farm machinery, industry employment and farm acreage were used.

Statewide Freight Planning Efforts

A 1993 Cambridge Systematics' survey of all 50 state DOTs posed the question, "do you develop plans for statewide freight transportation?" The highlights of the 38 states that responded were:

- Only 4 states answered yes.

- Ten other states commented they were developing statewide freight transportation plans or intended to in the near future.

- Of the 4 states that responded positively, 3 stated that freight planning was part of their transportation plan.[15]

The three states that claimed to have developed plans for statewide freight transportation were California, Florida, and New Jersey. These states were contacted for further information, documentation, and reports describing their efforts, a review of which is presented in the next section of this document.[15] Further research by Cambridge Systematics since that survey found that most states are now considering freight largely in response to the requirements of the intermodal management system.[25] Table 3 is a summary of the characteristics of the freight planning efforts of California,[26] Florida,[27] and New Jersey.[28]

There are similarities between these states' efforts. One is input from the private sector either from representation in FACs and technical committees or from surveys to investigate future economic trends. Another common characteristic is a reliance on existing data whenever possible.

In a general sense, the three statewide freight planning efforts take a different approach. Florida focuses on the transfer facilities of intermodal freight, focusing on where bottlenecks occur. New Jersey's approach is somewhat more strategic; they take a systemwide approach. California's efforts are the most comprehensive and most data and resource intensive. Its Intermodal Transportation Management System is a GIS-based freight transportation planning tool with a broad range of application. It is capable of analyzing the impacts of infrastructure and policy changes at corridor, local, regional, and statewide levels.

Hampton Roads Intermodal Management System

The most noteworthy freight planning effort in Virginia is the development of an IMS by the Hampton Roads MPO.[13] The Hampton Roads IMS addresses intermodal deficiencies for both passenger and freight transportation. The stated goals are:

- inventory major intermodal system facilities and conflict points
- identify intermodal access and deficiency problems
- evaluate relative effectiveness and efficiency of alternative transportation improvements and investments in the region
- assist state and local government officials in considering project selection decision
- provide adequate information to the private sector regarding the development and operation of an efficient intermodal transportation system.

The project is being undertaken in two phases. The first phase, which has been completed, accomplished the following tasks:

Identify intermodal system facilities and conflict points. Intermodal facilities were selected to include the roadway network developed for the congestion management system, primary routes of access to major intermodal facilities (ports, airports, transit stations, military installations, etc.), intermodal transfer facilities, major truck routes, and the multimodal transportation system in general.

Table 3: Summary of Statewide Freight Planning Processes

Tasks	**California**	**Florida**	**New Jersey**
Steps of the Freight Planning Process	1. Identify planning areas for analysis 2. Locate deficiencies 3. Develop actions and strategies 4. Evaluate performance impacts 5. Prepare reports	1. Criteria for programs and projects 2. Intermodal data system 3. Demand forecasting 4. Needs identification 5. Funding sources 6. Advanced technologies and innovative techniques 7. Strategy and action identification	1. Project initiation, coordination and outreach 2. Inventory of intermodal activity in New Jersey 3. Quantitative & qualitative assessment of national, state and regional economies 4. Assess New Jersey's market potential 5. Market based freight transportation and modal trends 6. Goals and vision for New Jersey's intermodal system 7. Establish performance measures 8. Baseline measure of performance and effectiveness 9. Market based freight transportation and modal needs assessment 10. Definition of future alternative scenarios 11. Strategies to reach goals 12. Continuing performance monitoring 13. Prepare Intermodal Strategic Plan and IMS
Private Sector/FAC Involvement	SIGMAC	Business surveyed for opinions on advanced technologies and regulatory barriers	• Intermodal Goods Movement Task Force • Technical Committee
Freight Performance Measures Used	Categories: • Mobility • Financial • Environmental • Economic • Safety • Quality of Life • Other • Intermodal transfer facility	Categories: • Physical Characteristics • Financial Characteristics • Service Characteristics • Usage Characteristics	• Truck turnaround time at terminals • Transit time between terminals • Crash rates • Direct and indirect jobs created • Percent of State Gross Product • Modal and intermodal share • Primary intermodal service schedule adherence • Secondary services status report
Freight Data Sources Used	TRANSEARCH database	Existing modal databases (ICC Waybill Sample)	DRI/McGraw-Hill's in-house freight, commodity, and trade database
Freight Forecasting Methods Used	TRANSEARCH database with 20 and 30 year projections based on forecasts of freight origins	Sketch Planning Guidelines: 1. Examine data available 2. Identify data gaps 3. Devise means to fill gaps 4. Determine modal splits from existing trends 5. Identify O&D pairs 6. Identify, obtain and use existing forecasts, or trend analysis 7. Identify impact on intermodal facilities	DRI/McGraw-Hill's in-house freight, commodity, and trade database

1. *Establish goals and objectives.* Fundamental values are defined as economic development and air quality responsibilities. Major goals are defined as:

    - *choices*, involves improving accessibility to intermodal facilities and increasing multimodal opportunities

    - *connections*, involves providing efficient transfer between modes

    - *coordination*, involves the improvement of coordination both between modes and between the public and private sector.

2. *Develop freight performance measures*. Freight performance measures relate to either modal choices, modal connections (physical limitations, terminal accessibility, transferability between modes, and safety), or modal coordination (public sector actions in support of the private sector).

3. *Establish a data collection plan*. The IMS will use existing or available data whenever possible, including data from other management systems and local and state agencies.

The second phase of the Hampton Roads IMS is underway. It involves the identification and analysis of intermodal deficiencies and possible solutions. The results of Phase 2 will provide information to assist in the development of their regional plans and programs. The components of Phase 2 include preparation of an intermodal deficiency plan, identification and evaluation of intermodal strategies, monitoring strategies, and program funding and implementation.

In addition, a Hampton Roads advisory task force guides the development of its IMS. The task force consisted of representatives from the following agencies:

- VDOT

- Virginia Department of Rail and Public Transportation

- FHWA

- Tidewater Transportation District Commission

- Peninsula Transportation District Commission

- Virginia Port Authority

- Virginia State Police

- Norfolk International Airport
- Newport News-Williamsburg International Airport
- Norfolk Southern Corporation
- CSX Transportation
- Transportation Trucking Association
- chairman of the technical committee representing local jurisdictions.[14]

Development of Methodology

This section describes a six-step freight transportation planning process. The process draws on the freight planning experiences of other states and planning agencies and includes methods that can provide useful results within the constraints of the current goods movement arena discussed in the literature review. The proposed statewide intermodal freight transportation planning methodology is shown in Figure 2. The process progresses from the

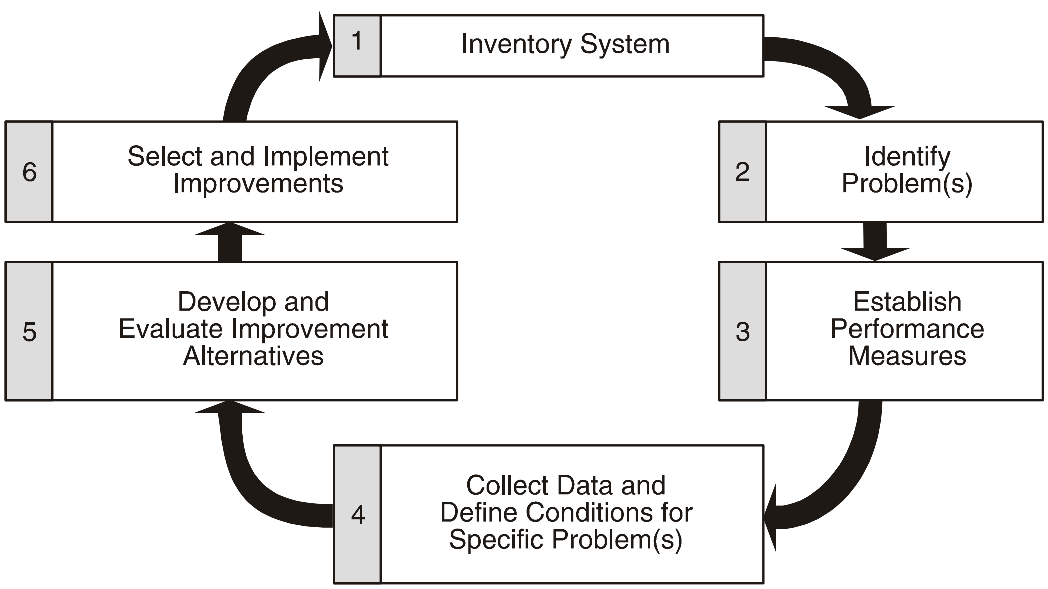

Figure 2. Steps of Statewide Intermodal Freight Planning Methodology

general to the specific. The procedure is intended to be continuous and evolving, where successive iterations provide more accurate and consistent results. This is possible because:

- The knowledge and skills of the planning professionals using the process will improve as they become more accustomed to the methodology.

- The relationship between public and private sector freight stakeholders will be strengthened, encouraging more private sector assistance in planning efforts.

- Investigation of specific planning problems will lead to a better understanding of freight flows, allowing for updated system inventories that more accurately depict actual conditions.

- Variables such as performance measures, indicators of production and attraction, and impedance factors will become better understood and can be adjusted to provide more accurate results.

Step 1: System Inventory

This step involves taking an inventory of the freight transportation infrastructure and freight flows by commodity and mode. This will allow an overall understanding of the state's current freight transportation system, which will facilitate the subsequent planning activities. In the early stages of freight planning, inventorying the goods movement system will be a major effort requiring significant planning resources. However, once the initial system inventory is completed, the system inventory will essentially be in place and will require less maintenance to remain updated and adjusted.

The steps involved in inventorying the system are shown in Figure 3. The process involves separate efforts to identify infrastructure elements of the network and to obtain and

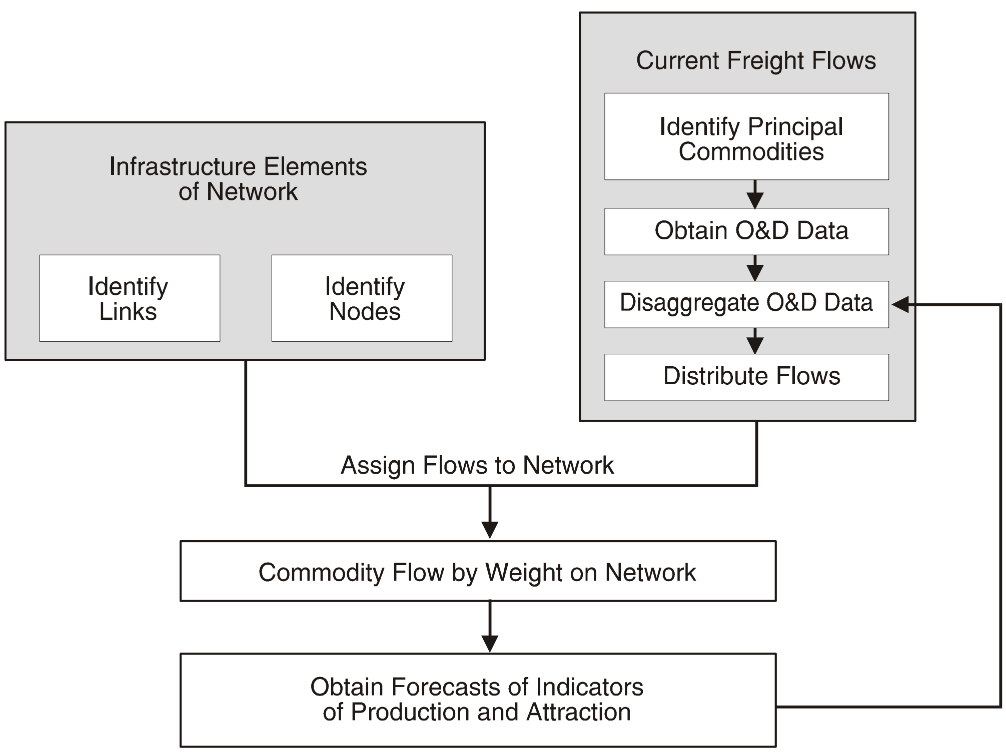

Figure 3. Inventory the System

manipulate freight flows. Once completed, the two efforts can be combined, yielding an inventory of the state's freight transportation system. This "base year" inventory can then be extrapolated forward to predict future freight flows.

Identification of Infrastructure Elements of the Network

Elements of a freight transportation network can be categorized as links and nodes. Components of links to be inventoried include interstate highways, primary roads, other roads with significant freight volumes, railroads, and waterways. Components of nodes include ports, airports, truck/rail transfer facilities, and truck/truck transfer facilities.

The National Highway System (NHS) is a good starting point from which to construct the highway network. The NHS is a nationwide network of roadways designated by FHWA. The system is composed of the interstate highway system, other routes designated as "strategic highway network corridors," network connectors for 242 military installations, and congressional high-priority corridors. The NHS also designates "intermodal connectors" that are served by NHS routes or require additional NHS connections.

Analysis of Current Freight Flows

Comprehensive freight transportation planning requires data on goods movement flows. Considering freight by weight is usually preferable to considering weight by vehicles because it allows for an analysis of how public infrastructure and policy decisions affect the important industries in the state. This is more useful than analysis of the contribution of freight vehicles to congestion, which is generally minimal and can be accounted for in more traditional planning efforts. However, vehicle counts can be obtained by weight-to-vehicle conversion factors. Conversion factors for different commodities are currently being researched and developed by the FHWA for inclusion in a freight data handbook that is expected to be published in mid-1998.

The overall goal of the system inventory is a goods movement network of routes and intermodal transfer points with assigned freight flows. To make this possible, it is necessary to arrange and manipulate freight flow data from the level of detail that is currently available to a level that is appropriate for assignment to a network. Once this has been accomplished for a "base year" the flows can be forecast for future years.

Identify Principal Commodities. To simplify the data collection and manipulation efforts, it may be useful to evaluate freight flows one commodity at a time, focusing on principal commodities that are determined to be most important to the state's economy. This "layered" approach was devised by Iowa State University's Center for Transportation Research and Education.[23]

To identify principal commodities, factors such as tons, ton-miles, and value shipped need to be considered. This information is available at the state level from the 1993 Commodity Flow Survey (CFS).[17] Tons and ton-miles indicate the use of the transportation infrastructure by each of the industry classifications. Bulk commodities, such as coal and nonmetallic minerals, typically contribute the most tons and ton-miles. Value shipped indicates the importance of the industry to a state's overall economy. Goods with high unit costs, such as food, chemicals, and electrical machinery, are often the leaders in value shipped, even though they are not heavy and may be less significant by weight. Another factor that can identify commodities important to the state's economy is employment data by industry associated with specific commodities.

Obtain O&D Data. The most readily available and widely used source for freight flow O&D data is the 1993 CFS. The CFS' state-to-state level of data are too aggregated for statewide freight planning, but they do provide a starting point and can be disaggregated to more detailed levels. CFS data are provided by 2-digit STCC and mode.

O&D freight flow data at more detailed levels are not currently published. If "starting point" data of greater level of detail than is provided in the CFS are required, it is likely that the information would have to be provided by consultants at a cost, as discussed later.

Disaggregate O&D Data. To disaggregate the starting point O&D data to a more useful level, a process of "proportioning" can be used. The process of disaggregation, distribution, and assignment to take starting point O&D data to freight flows on a network is shown in Figure 4.

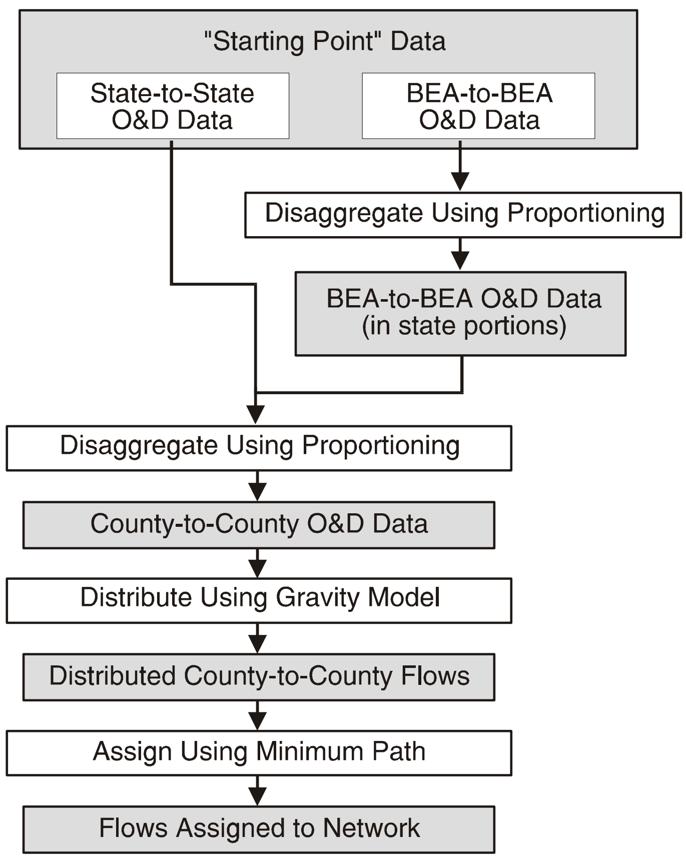

Figure 4. Disaggregating, Distributing, and Assigning Freight Flows

Freight that originates and destines within the state can be disaggregated among sub-regions by proportions according to production and attraction indicators. A similar process was used in the Iowa study discussed previously. [23]

The relationship used to proportion freight among counties can be stated as

$$TO_{ki} = (IP_{ki}/IP_{kr}) * TO_{kr}$$

$$TD_{ki} = (IA_{ki}/IA_{kr}) * TD_{kr}$$

where

TO_{ki} = tons of commodity k originating in sub-region i

TD_{ki} = tons of commodity k destined for sub-region i

IP_{ki} = indicator of production for commodity k in sub-region i

IP_{kr} = indicator of production for commodity k in the entire region

IA_{ki} = indicator of attraction for commodity k in sub-region i

IA_{kr} = indicator of attraction for commodity k in the entire region

TO_{kr} = total tons of commodity k originating in the region

TD_{kr} = total tons of commodity k destined for the region.

The tonnage of each commodity originating and destined for each sub-region can be calculated using the proportioning equations. The most likely starting point to use as the entire region would be the state. The sub-regions would probably be counties. If starting point data at a greater level of detail, such as BEA-to-BEA, are available, this could represent the entire region. However, working with these data would introduce additional complications, since the BEAs often contain counties in different states. For example, an extra disaggregation would be necessary to modify a BEA region so that it includes only the area within the state of interest.

Theoretically, the entire disaggregation process could be repeated, with the sub-regions from the previous iteration becoming the entire region. In this manner, the O&D data would become progressively more detailed. In practice, however, it is likely that flow data at a greater level of detail than county-to-county would be both inaccurate and unnecessary.

The most basic measure of production is industry employment. As mentioned previously, this information can be obtained at the county level from the Virginia Employment Commission (VEC). The most basic and commonly used measure of attraction is population, because it often relates to consumption and is widely available from databases such as those maintained by the Weldon Cooper Center for Virginia.[24] Employment levels and population are not the only variables that can be used as indicators of production and attraction. There may be more descriptive and accurate indicators, depending on the commodity. For example, the Iowa study used farm acreage as an indicator of attraction for farm machinery.[23] Farm acreage is a more logical choice as an indicator than population of popular shipping destinations for farm machinery, since the product is typically sold to farmers, not the general public, and there are few farms located in areas of dense population.

Distribute Flows. Once the data have been disaggregated to an appropriate level, the next step is to distribute the flows between O&D pairs. This can be accomplished using a gravity model, a familiar tool to transportation planners. The gravity model can be stated as

$$T_{kij} = TO_{ki}TD_{kj}F_{ij} / \Sigma_{j=1,n}TD_{kj}F_{ij}$$

where

T_{kij} = freight flow of commodity k between i and j

TD_{kj} = tons of commodity k destined for j

F_{ij} = impedance factor for i to j.

In its most basic form, the impedance factor is a function of the inverse of the distance between O&D pairs, in the form of [1/distance^n], where a typical value of n is 2.0. This factor can be estimated using a calibration process as described in *Traffic and Highway Engineering*.[29] If the data have been disaggregated to the county level, the O&Ds would be counties. The distance between counties could be between their area centroids. Alternatively, the distance between counties' main towns or cities could be used. This method could be more descriptive, since a county's major city often represents the center of activity and population. Distance between city pairs may also be easier to obtain, since these data are often published in conjunction with state maps.

Assignment of Freight Flows to Network

Once the freight flows have been distributed between O&D pairs, they can be assigned to the network. The simplest method would be minimum path assignment. This was used in the Iowa study with the aid of TRANPLAN, a program that is commonly used for assigning passenger flows.

Iterative procedures typically used in the assignment of flows for the movement of people, such as capacity restraint, should not be necessary to reach accurate assignments. This is because the loading of freight flows onto a link of the network has a minimal effect on the overall traffic on that link, and capacity concerns attributable to freight movement are rare. If it is felt that freight's contribution to congestion is an issue, as might be the case for railroads, then factors such as capacity, traffic volumes, and level of service could be considered, as suggested in the *Quick Response Freight Manual*.[22] This reference also recommends including weight/volume/height limitations on routes that could affect particular modes and vehicles.

For the rail and waterway modes, the choice of which link to place flows should usually be obvious, since there are not likely to be many optional routes. For goods moved by air, the airport closest to the point of origin can be selected. The truck mode could have more options, since the highway network is more intricate and provides more routing options than that of the other modes. Nevertheless, it should be possible to identify the most direct passage between the O&D pairs.

Obtaining Forecasts by Using Indicators of Production and Attraction

Forecasts of future freight flows can be obtained using forecasted indicators of production and attractions. The same indicators that were used to disaggregate freight flows for each commodity can be used. Forecasts will usually be available from the same sources as the base year indicators.

The county-to-county O&D data from the previous iteration (base year) can be projected to future years using the forecasted indicators of production and attraction. A linear projection is represented by the expression:

$$TO_{kif} = TO_{kib} * IP_{kif}/IP_{kib}$$

where

TO_{kif} = tons of commodity k originating in i in the future year

TO_{kib} = tons of commodity k originating in i in the base year

IP_{kif} = indicator of production for commodity k in i in the future year

IP_{kib} = indicator of production for commodity k in i the base year.

Similar expressions can be used to project freight destinations, using the forecasted indicator of attraction. The result is a new set of O&D data by commodity for the future year.

The forecast O&D data can then be redistributed to show future flows between regions. The distribution process performed earlier can be used again, but with the new, forecast O&D data and indicators of attraction and production. These distributed flows can then be reassigned to the network. The resulting freight flows by weight and commodity for the forecast year will be useful at later stages in the freight planning methodology to predict the future needs of the freight transportation system.

It may be necessary to use a “base year” other than the present year. This would be the case if the starting point data were CFS data, which is for the year 1993. Indicators of production and attraction used to disaggregate these data should be from the same year. After the disaggregation, distribution, and assignment of the base year flows, projections could be made to the actual present year in the same manner described for future years.

Role of FAC in Inventorying the System

A knowledgeable and experienced FAC can be useful in validating or adjusting the system inventory. For example, a railroad representative may have first hand knowledge that significant flows of scrap metal are shipped by rail between two counties, despite the fact that disaggregation process may have resulted in a system inventory that did not show this.

The FAC may also be able to suggest meaningful indicators of production and attraction. Shippers would have a detailed understanding of the freight flows in their industry and might have useful suggestions of variables that illustrate where goods are produced and the locations to which they are shipped. This knowledge can be used to develop more accurate indicators of performance than those based on employment and population levels.

By informing and involving the FAC in the freight modeling activities, the resulting system inventory will more accurately depict actual goods movement. This is critical to the freight planning methodology as a whole, since the inventory of the system is the initial step in the process, upon which subsequent steps will build.

Geographic Information System Platform for the System Inventory

A GIS format is an appropriate platform on which to create the freight transportation network. Some states, including Virginia,[30] have already begun assembling a GIS containing their freight transportation infrastructure, such as highways, railroads, ports, airports, and intermodal transfer facilities. With the freight flows that result from the system inventory assigned to the infrastructure elements as attribute data, the GIS freight database would become a powerful analysis tool to support statewide freight transportation planning.

Step 2: Identify Problems

This step identifies problems with the state's freight transportation system, including observable impediments or bottlenecks, and areas where opportunities for improvements exist. The main resources that can assist in the identification of problems are the FAC and the system inventory. Analysis of the network flow information that resulted from the process used to identify problems is shown in Figure 5.

Problems or opportunities for improvement related to goods movement include

- general traffic congestion
- restrictive vehicle size and weight regulations
- safety concerns with the transport of hazardous materials (HAZMATS)
- changes in freight flows attributable to price changes, mergers, or logistics trends

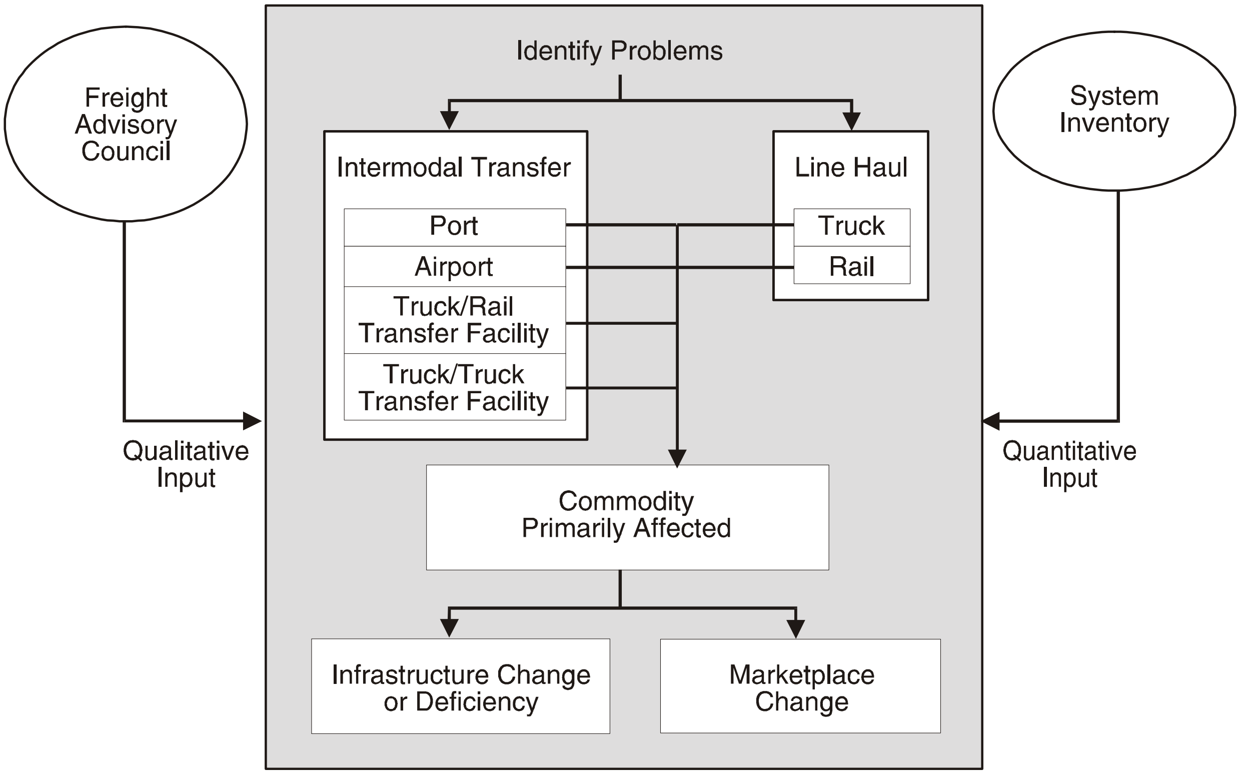

Figure 7. Identifying Problems

- inefficient operations leading to delays at intermodal transfer facilities
- limited hours of operation at intermodal transfer facilities
- excessive neighborhood truck traffic
- truck-related crashes
- lack of direct rail spurs to critical industry locations
- poor level of service of access roads to ports and airports.

Once freight transportation problems are identified, they can be categorized. Similar problems and solutions from the past can then be considered to assist the planning effort. Categorization will also aid subsequent planning steps, such as the selection of performance measures. Again, the resources to assist in categorizing problems are the FAC and the results of the system inventory.

Goods movement problems can be categorized by asking the following questions:

1. Which portion of the goods movement trip is primarily affected by the problem?

2. Which mode(s) are affected the most?

3. Which commodities are affected the most?

4. What is the nature of the issue?

Step 3: Establish Performance Measures

Performance measures will vary depending on the type of freight transportation problems being addressed. The appropriate performance measures for a specific issue can be selected from Table 4, since all performance measures will not apply to all types of problems. The recommended freight performance measures illustrated in Table 4 are based on the most meaningful, measurable, and realistic freight performance measures recommended by FHWA[8] and developed by other states and planning organizations, particularly CALTRANS.[26]

The categorization of problems performed in Step 2 will provide a guide for the selection of performance measures. Performance measures are grouped so they apply to line haul or intermodal transfer facility issues (or both).

The selected freight performance measures will be used in Step 5 and will provide an objective evaluation of improvement alternatives. It is important that they are established before alternatives are generated to increase the likelihood of impartial evaluation.

Step 4: Collect Data and Define Conditions for Specific Problem

There are two main components to this step. The first is a more detailed and focused investigation of the specific freight transportation problems. This is necessary to narrow the scope of the analysis and provide a more microscopic view than is possible from the system inventory. The second component is to collect additional data to enable the use of the performance measures established in Step 3.

The system inventory defined the condition of the freight transportation system for the state as a whole. Since the scope was then narrowed in Step 2 to specific problems and opportunities for improvement, it is necessary to focus in on these issues and define conditions in more detail for specific problems and locations.

Since any freight flow data that can be modeled at a microscopic level were most likely derived and disaggregated from a more macroscopic level, it is expected that inaccuracies and inconsistencies will exist. Some of these can be "ironed out" with the assistance of the FAC, who can provide more realistic information based on their actual experience and use of the facility or infrastructure. The FAC might also be able to paint a clearer picture of the future than was possible with the forecasts performed in the system inventory. For example, a railroad operator on the FAC might be able to provide information on a future rail merger and how it might shift freight flows by mode.

Table 4: Performance Measures for the Statewide Intermodal Freight Planning Methodology

Trip Portion /Facility Type	Performance Measure Category	Performance Measure	Formula	Data Requirements
Line Haul	Mobility	Ton miles per hour	Weight/(Distance*Time)	Weight, distance, time
		LOS	Volume/Capacity	#lanes/tracks, demand
		Vehicle hours of delay	Actual time/theoretical time	Free flow time or speed, actual time or speed
Line Haul	User Cost	Cost per ton mile	Annual Equivalent Cost/Ton mile	Capital, operating, and maintenance costs, weight, distance
Intermodal Transfer Facility (ITF)	External Measures	Number of modes with access	Number	Facility access characteristics
		LOS of access route	Volume/Capacity	# lanes/tracks, demand
		Distance to interstate access point	Distance by most direct access road	Route lengths
		Distance to nearest rail terminal	Distance by most direct access road	Route lengths
		Vehicle hours of delay at grade crossings	Stopped time/day	Stopped time for trains and trucks
		Number of bridge height restrictions	Number	Bridge heights, vehicle heights
		Number of turning radii restrictions	Number	Turning radii, vehicle size and configuration
Intermodal Transfer Facility (ITF)	Internal Measures	Throughput	Weight/Day	Tons handled by facility
		Transfer time	Time at facility per ton	Average handling times
		Hours of operation	Hours open per day	Facility open hours
		Number of turning radii restrictions	Number	Turning radii, vehicle size and configuration
Both Line Haul and ITF	Safety	Accidents per million ton miles	Accidents/million ton miles	Accidents, weight, distance
		Fatalities per million ton miles	Fatalities/million ton miles	Fatalities, weight, distance
Both Line Haul and ITF	Environmental	Pollution	Pollution/ton mile	Pollutants, weight, distance
		Fuel consumption	Fuel/ton mile	Fuel, weight, distance
Both Line Haul and ITF	Impact on Economy	Number of jobs created	Construction jobs + operating jobs	Capital, operating and maintenance cost, useful life, employment multipliers

The performance measures established in the previous step may require data not included in the system inventory. For example, information on crash rates was not inventoried in Step 1 but may be necessary for the safety performance measures. Data collection efforts for performance measures should not be overly intensive, since the specific problem and performance measures were defined in Steps 2 and 3.

If data for a performance measure cannot be obtained, or obtaining it would be too difficult, costly, and time-consuming to be worthwhile, the performance measure should not be disregarded. It is still important, and should be considered, although most likely in a more qualitative regard. For example, if it is not possible to determine the number of new jobs that will be created for a particular improvement alternative, that performance measure should not be ignored. A relative estimate could be made to compare the likely impact on jobs of one alternative to another. Ideally, the analysis would show, for example, that alternative A creates X new jobs, and alternative B creates Y new jobs. If the data do not allow this, it may be necessary to estimate that alternative A creates more or fewer jobs than alternative B.

Step 5: Develop and Evaluate Improvement Alternatives

Step 5 in the freight planning methodology, developing and evaluating improvement alternatives, is portrayed in Figure 6.

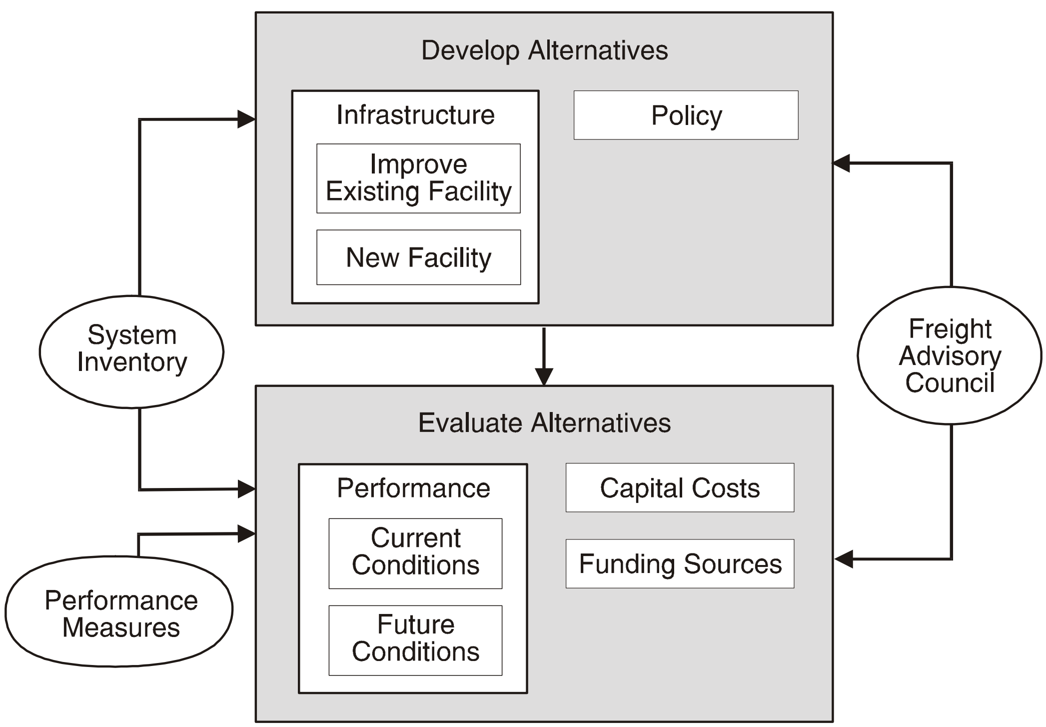

Figure 6. Developing and Evaluating Alternative Improvements

Development of Alternatives

The development of alternatives is essentially a brainstorming exercise that would best be performed by the FAC. Alternatives could be either infrastructure improvements or policy changes. Infrastructure changes include facilities such as ports, highway, and highway/railroad crossings and can involve either the improvement of an existing facility or the introduction of a new facility. Examples of infrastructure changes are the introduction of a truck weigh-in-motion facility or bridge alterations to allow double-stack rail.

Policy changes include government regulations and programs that can affect freight transportation, such as size and weight regulations and vehicle registration fees and taxes. The impact of government policies can be far-reaching and should not be underestimated. They can shape the future of a region's economic development and cause shifts with respect to mode choice, routes, tonnage, and commodities shipped.

The basis for evaluating improvement alternatives should be the performance measures established in Step 2. This will provide a consistent and fair evaluation of each alternative, showing how it relates to the overall goals for the freight transportation system.

Each alternative should be analyzed to show how it will affect the freight transportation system under both current and forecast conditions. This information is available from the results of Step 1. A freight transportation system inventory in GIS format would be particularly useful in evaluating alternative improvements. Possible changes in the freight transportation system could be added to the GIS freight database to view their effects on future and current goods movement. In this manner, the combined effect of more than one improvement can also be viewed, enabling the development of improvement packages consisting of actions that complement each other.

It will also be necessary to estimate the capital costs of each alternative, including construction costs and maintenance costs. When the capital costs for an alternative are viewed concurrently with the benefits that are derived from the performance measures, an indication of the value that can be gained for the investment of public funds is provided. If benefits and costs can be quantified in a reasonably comprehensive manner, methods such as benefit/cost and net present worth analysis may be appropriate. These methods should be used with care, however, since benefits and costs are often hidden or difficult to quantify in like terms.

Possible funding sources should also be identified. *Intermodal Freight Transportation, Volume II, Fact Sheet and Federal Aid Eligibility* lists options for receiving federal funding for intermodal freight projects under ISTEA, including:

- NHS Funds
- Surface Transportation Program General Grants
- Congestion Mitigation and Air Quality Improvement Funds

- Bridge Replacement and Rehabilitation Program
- Priority Intermodal Projects (Demonstration Projects).[31]

Funding sources under subsequent transportation legislation should also be pursued.

Transportation improvements that benefit goods movement lend themselves to public/private partnerships and opportunities to leverage private sector funding that should be investigated. The FAC could prove an important forum to discuss these options. Private businesses may be willing to share the capital cost of transportation improvements that will benefit their industry, particularly if their investment can speed up the process and reduce the time horizons for project completion.

Transportation improvements are judged by multiple criteria, and it is often difficult to express the performance of alternatives for different criteria in like terms. For this reason, it may not always be possible or appropriate to definitively say that one alternative is “the best.” However, transportation projects do compete for finite resources and funds, not just against other transportation projects, but also against other programs requiring public investment, such as education and law enforcement. The evaluation of improvement analysis should enable the pros and cons of each alternative to be stated, compared, and used to develop a list of priorities. This would assist decision makers in determining where to invest public funds.

Step 6: Select and Implement Improvements

The final decision on which improvements to implement is not the sole responsibility of transportation planners. The planner’s role is to inform the decision makers, typically politicians, on the issues at hand and the relative merits of alternative actions. This information should be presented in a clear and complete fashion. To assist in the selection of improvement alternatives for implementation, decision makers have three main resources:

1. overall goals and vision for the transportation system
2. prioritized list of improvements from Step 5
3. budget constraints and funding availability.

Decisions will be based on a balance among these three criteria, so that the improvements selected are consistent with the overall goals for the state’s transportation system, are identified by the freight planning process as definite needs, and are financially feasible.

Once the selected improvements have been implemented, the resulting changes in the freight transportation system should be monitored to determine if they are performing as expected. Differences between expected and actual outcomes should be included and accounted for in future iterations of the freight planning methodology. The monitoring of implemented improvements will contribute to the continuous learning process for freight planners. For instance, actual freight flows through a new intermodal facility should be observed and compared to flows that were forecast. The comparison will be useful in subsequent modeling efforts and may allow a more accurate calibration. Communication with the private sector users of the freight transportation system will once again be an important resource for monitoring improvements. Participants of the FAC can provide immediate feedback on the improvements and whether they are having the desired effect.

Case Study

The methodology developed for statewide freight transportation planning integrates a series of technical planning tasks with an ongoing dialogue with stakeholders in the process through a FAC. Although planners continually work with participant groups in the planning process, this task is not new here, just the focus. However, analytical methods usually need to be explicitly demonstrated. Accordingly, this case study will show only the technical tasks of the methodology. In this regard, the system inventory, the most complex and technical step of the methodology, is not heavily dependent on input from a FAC and, therefore, can be performed in detail in this case study. The subsequent steps are discussed in less detail, with a focus on how they are supported by the system inventory.

The subject matter of this case study was selected because it was considered to be an important goods movement issue in Virginia that could benefit from an organized planning effort using a standard methodology.

Electrical goods are Virginia's third ranked commodity by value of goods shipped, and their manufacture is one of the fastest growing industries in Virginia.[17] The emergence of Virginia as a prime location for high-technology electrical goods industries is evidenced by the two new Motorola manufacturing plants being introduced in central Virginia. The White Oak Semiconductor facility in Henrico County, 22.5 km (14 miles) east of Richmond, will begin production in 1998, producing between 1,000 and 1,500 new jobs. The West Creek Campus facility in Goochland County, 48.3 km (30 miles) west of Richmond will follow in the year 2000, with 2,500 new employees. This case study applies the freight planning methodology to predict the future movement of electrical goods throughout Virginia, including the contribution of the new Motorola manufacturing plants.

Step 1: System Inventory

This step represents a major effort of the planning methodology and is given the most attention in the case study.

Identify Principal Commodities

For this case study, the commodity of interest is Standard Industrial Classification (SIC) 36, manufacturing of electrical machinery, equipment, and supplies. The goods being produced at Virginia's new Motorola semiconductor plants are included in this category.

Obtain O&D Data

For Virginia as the state of origin, the 1993 CFS[17] was used to obtain goods movement data on SIC 36 shipments by mode of transportation in value, tons, and ton-miles. Only the motor carrier mode is analyzed in this case study, since the CFS shows that 96 percent of the weight of SIC 36 freight that originates in Virginia is shipped by truck.

The CFS reports that 365 thousand tons of truck-shipped SIC 36 freight originates in Virginia each year. The portion of this SIC 36 freight that is shipped within Virginia is not disclosed in the CFS, but it is assumed to be 71.6 percent, the average for all commodities originating in Virginia. Using this percentage, the 1993 SIC 36 internal-internal (I-I) freight is 261 thousand tons.

Internal-external (I-E) movements were included in the analysis from Virginia to neighboring states (North Carolina, West Virginia, Maryland, and Tennessee) and Pennsylvania. These are the states, according to the CFS, with which Virginia exchanges most of its electrical goods. Kentucky and the District of Columbia were not included in the analysis of I-E movements, since the CFS data were suppressed for Kentucky and omitted for the District of Columbia. The amount of SIC 36 shipped from Virginia to each of these states is not directly stated in the CFS, so more estimates were necessary. It was assumed 0.126 percent of total freight from Virginia to each other state is SIC 36. This is the percentage of all freight originating in Virginia that is electrical goods. The estimated tonnage to each state is shown in Table 5.

Table 5: 1993 SIC 36 I-E Freight Tonnage

Destination	**Shipments from Virginia (1000s tons)**	**% SIC 36**	**SIC 36 from Virginia (1000s tons)**
Pennsylvania	7299	0.126	9.20
North Carolina	19688	0.126	24.80
West Virginia	6241	0.126	7.86
Maryland	8982	0.126	11.30
Tennessee	5714	0.126	7.20

External-internal (E-I) data are not available from a single source, since the CFS does not include a document of goods movement for Virginia as the state of destination. Instead, the documents for each other state of interest as the state of origin were consulted to find the freight shipped from that state to Virginia. To review all states would be an arduous task and is unnecessary since distant states have little or no exchange of electrical goods with Virginia. In this example application, only Pennsylvania and the states bordering Virginia were included in the analysis of E-I movements. The amount of SIC 36 goods shipped to Virginia from each origin state can be estimated using the assumption that the same percentage of the origin state's SIC 36 shipments are destined for Virginia as the total for all commodities. Again, this assumption is necessary because the CFS contains no table of goods movement by commodity type and state of destination. The resulting tonnage to Virginia estimated from each state is shown in Table 6.

Table 6: 1993 SIC 36 E-I Freight Tonnage

Origin	SIC 36 to All States (1000s tons)	% Freight (all commodities) to Virginia	SIC 36 to Virginia (1000s tons)
Pennsylvania	1244	0.8	9.95
North Carolina	979	5.6	54.80
West Virginia	155	11.6	18.00
Maryland	279	8.0	22.30
Tennessee	1613	1.5	24.20
Kentucky	1053	2.1	22.10

External-external (E-E), or "pass-through," shipments were not included in this case study because they are difficult to predict and are of lesser importance to manufacturers of electrical goods in Virginia.

Disaggregate O&D Data

For an inventory of SIC 36 transportation in Virginia, the state-to-state CFS data were disaggregated to more detailed levels. Flow data by county was selected as an appropriate sub-state level that allows for a detailed analysis of SIC 36 movements.

The process of disaggregation involves proportioning using indicators of production and attraction.

The total of Virginia's SIC 36 origin freight for I-I and I-E movements is simply divided among Virginia's counties and cities, according to the proportions of indicators of production. Likewise, Virginia's destination freight for I-I and E-I movements is divided among counties and cities according to indicators of attraction. The employment, population, and resulting forecast freight for 1993 SIC 36 movements are shown in Appendix A.

Employment in SIC 36 is used as the indicator of production. This information was obtained from VEC. The use of employment as an indicator of production implies the assumption that employees in SIC 36 contribute the same amount of freight regardless of the company and location in which they work.

A combination of employment in SIC 36 and population was used as the indicator of attraction, with an equal contribution from each of the two factors. Population is a logical indicator for consumer goods, since the largest markets are generally population centers. Population data are also a convenient indicator, since they are widely available and easily obtained. In this case study, population data for Virginia's counties and cities was obtained from the Weldon Cooper website.[24] Some electrical commodities could be considered consumer goods, such as cellular telephones, stereos, and computers. However, other electrical goods, such as semiconductors and microchips, are used as components of other products. These goods are more likely to leave manufacturing facilities destined for other SIC 36 plants to be used as inputs to production. The dual function of electrical commodities as consumer goods and inputs to production is the basis for using a combination of population and employment as the indicator of attraction.

Techniques for Filling Gaps in Employment Data. The employment data for SIC 36 obtained from VEC included employment levels by industry and location. The locations are counties and cities in Virginia, and can be referred to as Federal Information Processing Standard Regions (FIPS). In Virginia, cities are considered separately from the county in which they are located, so it is necessary to account for both cities and counties when assembling statewide data.

VEC data are publicly available at no charge, but there is some disclosure suppression that can lead to data gaps. The suppression is deemed necessary to protect individual businesses and is applied whenever information on a single company could be extrapolated from the FIPS data. The missing data can be obtained from VEC by requesting a "run" on their database, but there is a cost involved (usually $50 to $200 depending on the amount of data requested) and an agreement must be signed to ensure that no information on individual firms is published. An alternative to purchasing the complete data set is to fill the gaps through various techniques and assumptions. These skills would be useful whenever a complete data set is not available, either because of excessive cost or because the data do not exist.

For the Motorola sample application, VEC data were obtained for SIC 36, first quarter of 1993, for Virginia's counties and cities. Forty-five of the 135 FIPS are suppressed, making the data set essentially 67 percent complete. To estimate the SIC 36 employment in the missing FIPS, four gap-filling techniques were applied to the dataset. The results were compared to the actual employment levels, which were purchased from VEC.

Technique 1. "Back-out" FIPS employment data from larger regions. VEC also provides employment data at the level of planning district commission (PDC) and service delivery area (SDA). VEC data at these levels are subjected to less disclosure suppression. There are 21 PDCs in Virginia, each composed of a selection of FIPS. SDAs are regions used by VEC and are composed of one or more PDC. If there is only one FIPS with disclosure suppression within a PDC, the employment can be calculated by subtracting the sum of the other FIPS in the PDC from the total employment in the PDC. Similarly, PDC data can be "backed out" of SDA or PDC data.

Example of technique 1 from the Motorola case study:

PDC 15 Employment = Sum of employment of cities and counties in PDC 15
2,538 = Employment of Charles City County = 0
+ Chesterfield County = 215
+ Goochland County = 0
+ Hanover County = 57
+ Henrico County = unknown due to disclosure suppression
+ New Kent County = 0
+ Powhatan County = 0
+ Richmond City = 156

Henrico County Employment = 2,538 – (215 + 57 + 156) = 2,110

The purchased VEC data show that the actual 1993 employment in SIC 36 for Henrico County was 2,115. The gap-filling technique provided a result with only 0.23 percent error in this case.

Technique 2. Assume that the employment for a particular FIPS has not changed over the course of a few years. Disclosure suppression sometimes affects a FIPS in one year, but not in another. For example, Henrico County might be subjected to suppression in the 1993 SIC 36 data but not the 1995 data. If the assumption is made that the SIC 36 employment in Henrico County did not change in that 2-year period, then the 1995 data can simply be used in 1993. The assumption will obviously not always be correct, but it does provide an estimate or "ballpark" figure of the industry employment. The closer the two years are, the more reasonable the assumption that employment did not change.

Example of technique 2 from the Motorola case study:

The SIC 36 employment for the city of Bristol is subjected to disclosure suppression for 1993, but 1997 VEC data show it to be 866. Using gap-filling technique 2, the 1993 employment for Bristol is also 866. The purchased data from VEC show that the actual 1993 employment was 850, for an error of 1.8 percent.

Technique 3. Group together neighboring FIPS. If neither technique 1 nor 2 is applicable, it may be possible to group neighboring FIPS and calculate their combined employment. This approach is reasonable when two or more neighboring FIPS in the same PDC or SDA are subjected to data suppression. The individual FIPS' employment cannot be backed out as in the first gap-filling technique, but the difference between the PDC or SDA employment and the known FIPS' employment is the combined employment of the unknown FIPS. If the unknown FIPS are neighbors, they can be combined to form a new analysis region, with the employment of the combined FIPS being the employment of the new region. Although combining FIPS does not provide the same level of detail as data for individual counties and cities, it is still useful and applicable to statewide planning.

Example of technique 3 from the Motorola case study:

The counties of Charlotte, Nottoway, and Prince Edward and the City of Petersburg are subjected to data suppression, but they can be grouped since they are relatively close. Their combined employment is the employment of SDA 9 minus the employment of the known FIPS in SDA 9, that is, 1,092 – 594 = 498. To check the accuracy of this gap-filling technique, the actual FIPS' employment from the purchased VEC data can be added. This yields a combined employment of 386, or a 29 percent error in the estimation.

Technique 4. Group together FIPS into PDCs or SDAs. In instances where the majority of the FIPS within a PDC are subjected to disclosure suppression and the unknown FIPS are not neighbors, the best approach may be to express the data at the PDC level. If the PDC employment is also suppressed, then SDA will be the most detailed level that can be expressed.

This technique allows for some analysis despite the disclosure suppression, although results will be less detailed and will not show flows between FIPS within the PDC that have been aggregated. In some instances, this might not be critical. For example, in the analysis of the new Motorola plants in Henrico and Goochland counties, aggregating counties into their PDCs in Southwest Virginia to overcome disclosure suppression would provide a reasonable level of detail. This is because the general direction of the goods movement from the Motorola facilities can still be modeled, even though the flows to the individual counties in Southwestern Virginia would not be included. The greater the distance from the main point of interest for the planning problem, the lower the level of detail necessary.

Example of technique 4 from the Motorola case study:

PDC 4 has four of its five FIPS subjected to 1993 data suppression, the counties of Floyd, Giles, and Pulaski and the City of Radford. The only applicable gap-filling technique in this instance is to state the employment for the entire PDC, that is, 1,968 employees.

Sequential and Iterative Use of Gap-Filling Techniques. The gap-filling techniques should be used in the order shown. The first method is the most dependable and is likely to yield the most accurate results. If the first technique cannot be applied, then the second can be attempted, and so on. Once all four gap-filling techniques have been performed, they should be repeated in order. This might allow for more gaps to be filled, for example, a PDC might contain three counties with data suppression before the gap-filling techniques. After the first iteration of gap-filling techniques, the PDC only has one unknown county, which can be calculated using the first technique in a second iteration.

Success of Gap-Filling Techniques in the Motorola Case Study. Using gap-filling techniques 1 and 2 on the 1993 SIC 36 employment data, the number of unknown FIPS was reduced from 45 to 23. The remaining unknown FIPS accounted for only 5 percent of the state's employment in SIC 36. Gap-filling techniques 3 and 4 can be applied to the remaining unknown FIPS, grouping neighboring FIPS or aggregating to the PDC or SDA level.

The accuracy of the results from the gap-filling techniques was determined using the employment data purchased from VEC. These data include the SIC 36 employment of the FIPS that were subjected to disclosure suppression in the original employment listing. Average and absolute errors are shown in Table 7.

Table 7: Average Errors for Gap-Filling Techniques 1 and 2

Technique	Average Absolute Error	Average % Error
1	36.8	8.5
2	79.4	27.0
1 (post 2)	106.8	14.2
All 1 and 2	90.4	20.5

Reducing the Dataset. To make consequent calculations more manageable, the dataset was reduced after the disaggregation step. There are a total of 135 counties and cities in

Virginia, which would form a matrix of 135 x 135, or 18,225 O&D pairs. To distribute, assign, and forecast the freight flows between every county and city is time-consuming and unnecessary, since many of the O&D pairs contribute little or no SIC 36 freight.

The counties and cities whose cumulative forecast freight constituted 90 percent of the state's total freight were included in the reduced dataset. The other counties and cities were assumed to have negligible contribution to the movement of SIC 36 freight in Virginia.

To reduce the dataset further, cities were combined with the counties in which they are contained. In this manner, joined regions were formed, for example, Albermarle/Charlottesville.

These two reduction measures reduced the dataset from 135 counties and cities to 45. This represents a substantial reduction in the number of O&D pairs from 18,225 to 2,025.

Distribute Freight Flows

Flows between O&D pairs were distributed using a gravity model. The formula for the gravity model used was:

$$T_{kij} = TO_{ki}TD_{kj}F_{ij}/\Sigma_{j=1,n}TD_{kj}F_{ij}$$

where

T_{kij} = freight flow of commodity k between i and j

TD_{kj} = tons of commodity k destined for j

F_{ij} = impedance factor for i to j = 1/[distance from i to j]^{n}

The regions represented by i and j were Virginia cities and counties and Virginia's neighboring states and Pennsylvania.

The inverse of the distance between O&D pairs was used for the impedance. To simplify calculations for this case study, a value of 1 was used for n. Distances were calculated from state maps and mileage charts. Distances to and from counties were estimated using the town or city that is considered the county seat. For distances to and from other states, an approximation of the state's area centroid was used. Distance from one county to itself was set at 32.2 km (20 mi), and from one city to itself at 16.1 km (10 mi).

The resulting distributed flows will have origin freight for each region that matches exactly with the origin tonnage that was calculated in the disaggregation step. This is because the distribution was based on origin freight. Distributed destination freight, however, will not necessarily match the predistributed totals. For example, 1993 Augusta County destination SIC 36 freight was calculated as 1,232 tons in the disaggregation step but is only 1,186 tons after the distribution step. Adjustment and reiteration of the gravity model, as in passenger travel forecasting, would result in a convergence of these values. However, in the case study, only the initial iteration of the distribution was performed.

At this point, the dataset was again reduced, eliminating O&D pairs with insignificant contributions to overall SIC 36 goods movement. O&D pairs with SIC 36 flows below 150 tons per year were assumed to be negligible and were set to zero. This further reduced origin freight by 11.1 percent and destination freight by 8.6 percent.

The result of the distribution is a matrix of 1993 SIC 36 flows between Virginia counties and cities and the neighboring states. This matrix is shown in Appendix B.

Forecast Freight Flows

The distributed flows in Appendix B are based on 1993 CFS data. Both of the new Motorola plants will be open for production in the year 2000; therefore, the 1993 SIC 36 flows were projected forward by 7 years.

There were two main tasks to project the freight flows from the base year to the forecast year. The first was to project the overall SIC 36 freight tonnage in Virginia, including I-I, I-E, and E-I movements. The second was to recalculate the indicators of production and attraction for Virginia's counties and cities, and repeat the steps of disaggregation, distribution, and assignment using the new indicators.

The overall freight tonnage moved in Virginia was projected at the same rate as statewide employment in SIC 36. VEC supplied SIC 36 employment statistics for 1993 and 1997. The growth (or decline) in this industry between 1993 and 1997 was assumed to continue at the same rate through the year 2000. From 1993 to 1997, the overall statewide employment is SIC 36 grew at 0.63 percent per year. Freight tonnage is assumed to be proportional to the number of employees in the industry, so the 0.63 percent yearly growth rate was applied to estimate the total freight originating in Virginia. The electrical goods industry in Virginia's neighboring states was assumed to be growing at the same rate, so the 0.63 percent growth rate was used for E-I movements.

Indicators of production and attraction for 2000 were estimated using projected employment rates and population by county and city. The original, non-reduced dataset was used to ensure inclusion of counties that were previously assumed to have negligible contribution to SIC 36 flows but have grown significantly by the forecast year. The dataset was reduced again after the indicators for all counties and cities have been projected. The resulting matrix of forecast year distributed flows is shown as Appendix C.

Add Motorola's Contribution to SIC 36 Freight

The SIC 36 freight that will be generated from the two new Motorola plants was estimated based on the number of employees who will work at each plant. The statewide ratio of

SIC 36 employees to freight produced was used. In 1993, 30,724 employees created 365 thousand tons of SIC 36 freight, or 11.88 tons per employee. Assuming employee productivity is the same in the year 2000, and applying the same ratio to the new facilities, 1,500 employees at the White Oak facility in Henrico County would produce 17,820 tons of freight in the year 2000. Similarly, the West Creek facility in Goochland County would produce 29,700 tons.

Motorola's SIC 36 freight contribution was added to the overall freight tonnage produced in Virginia in the year 2000, and the indicators of production and attraction were adjusted. It is necessary to adjust the indicators of production and attraction for all of Virginia's counties and cities, since they no longer contribute the same percentage of statewide SIC 36 employment after the inclusion of the new Motorola plants. In particular, the introduction of the new facilities will alter the destination freight for each county, since the Motorola plants represent new attractions that will "pull" more SIC 36 freight to Henrico and Goochland counties. The resulting O&D flow matrix is shown in Appendix D.

Assign Flows to the Transportation Network

The distributed SIC 36 freight flows were added to the transportation network using an all-or-nothing assignment onto the route that provided the shortest path. The transportation network used consists of Virginia's interstate highways and primary routes. The shortest path was approximated using highway maps, but flows from a county or city to itself were not assigned.

I-E flows were assigned to a route as if the freight was destined for the area centroid of the out-of-state region. Similarly, E-I flows were assigned as if originating in the center of the external state. I-E and E-I flows were assigned to the network for only the in-state portion of their trip.

The result of the assignment for SIC 36 freight in the year 2000, including the addition of the two new Motorola plants, is shown in Figure 7. The volumes shown in the figure are in units of tons per year. Conversion from tons to vehicles would require a determination of typical vehicle size for the shipment of electrical goods, from which a conversion factor could be derived.

Completeness of the System Inventory Results

The system inventory for SIC 36 freight required a substantial effort, but it should be noted that the resulting freight flows are only a tiny fraction of all freight flows in Virginia. SIC 36 accounts for only 0.126 percent of the total freight tonnage that originates in Virginia. This set of freight flows is reduced even more at several stages in the system inventory. These reductions are:

- Motor carrier was the only mode considered, and it accounts for 96 percent.

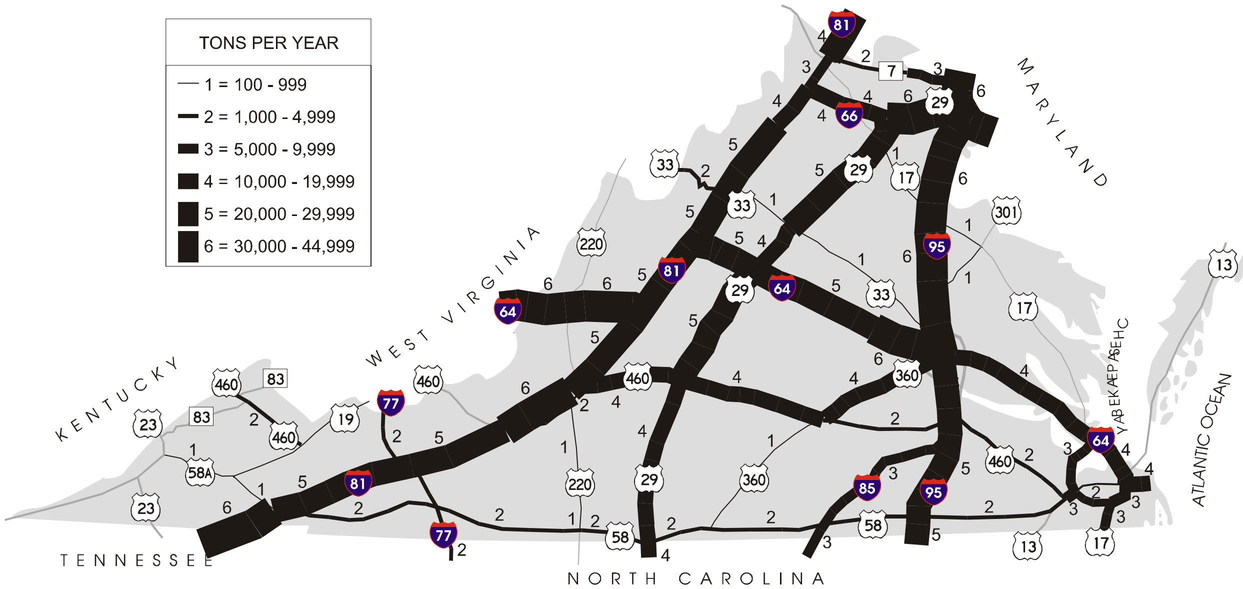

Figure 7. Virginia's SIC 36 Assigned Freight Flows for the Year 2000, Including New Motorola Plants

- Only the states that are Virginia's major trading partners were considered for I-E movements, and this accounts for 88 percent.

- Counties with insignificant SIC 36 origins were eliminated, and this accounts for 99 percent.

- O&D pairs with insignificant SIC 36 flows were eliminated, and this accounts for 90 percent.

The combined effect of these reductions was a SIC 36 dataset that is 75 percent complete (0.96 x 0.88 x 0.99 x 0.90). Therefore, the freight volumes in the system inventory represent approximately 75 percent of 0.126 percent, or 0.095 percent, of the total freight tonnage that originates in Virginia.

Step 2: Identify Problems

Without a FAC, it is difficult to identify location-specific problems and bottlenecks. If a FAC existed, private sector shippers and carriers, particularly those involved with the electrical goods industry, could bring to light any obstructions or delays they experience. However, the system inventory does provide a review of SIC 36 goods movement throughout Virginia and indicates the highways of greatest importance to the industry. Improvements to the routes most heavily used by SIC 36 are likely to provide the most benefit to the industry.

Figure 7 shows that the most important routes to Virginia's electrical goods industry are I-95, I-81, I-64, and portions of I-66 and Route 29. The highways around Richmond and Northern Virginia are particularly well used. It is noteworthy that pass through truck traffic was not included in the system inventory. If it were, I-81 and I-95 would become even more significant, since these routes are typical heavily used for through traffic. Conversely, transportation improvements in Southwest Virginia and the upper and middle peninsulas of Eastern Virginia would be of less benefit to the movement of electrical goods, since, with the exception of I-81, there is little SIC 36 activity in those areas.

The inclusion of the Motorola facilities in Goochland and Henrico counties has a major effect on Virginia's SIC 36 freight flows. The impact of the Motorola plants on SIC 36 and origin freight for these counties is shown in Table 8.

Table 8: Impact of Motorola Plants in Goochland and Henrico Counties

County	SIC 36 Employment		I-I Origin Freight (tons per year)	
	2000 without Motorola	2000 with Motorola	2000 without Motorola	2000 with Motorola
Goochland	0	2500	0	29,700
Henrico/Richmond	3,947	5,447	38,508	52,515

Goochland County, which currently has no SIC 36 activity, will become the fourth largest employer in Virginia for the electrical goods industry after the opening of the West Creek facility. The Henrico/Richmond area, already Virginia's largest employer in the electrical goods industry, becomes an even stronger SIC 36 center with the opening of the White Oak facility. Because of their geographic proximity, less than 80.5 km (50 mi apart), the flow of electrical goods between these two counties will be especially heavy. With the inclusion of the new Motorola plants, Table 4 shows that an estimated 4,973 tons of SIC 36 freight will be shipped from Goochland to Henrico counties in the year 2000, and 2553 tons from Henrico to Goochland. This makes truck routes between Henrico and Goochland counties, primarily I-64, particularly important to the electrical goods industry.

Another observation from the system inventory that might be considered a "problem" is the dominance of the truck mode for the transport of SIC 36 goods. Rail is most attractive for bulk commodities, such as coal and lumber, and is not an obvious choice for electrical goods. However, air transportation is a logical mode for time-dependent, high value commodities such as SIC 36 and would most likely play a role if more distant shipments were a factor.

Step 3: Establish Performance Measures

As indicated by the system inventory, almost all SIC 36 movements in Virginia considered here are made by the truck mode, so the performance measures selected will emphasize the line haul portion of transportation, rather than intermodal transfer. From Table 5, appropriate line haul measures are selected and categorized by mobility, user cost, safety, environment considerations, and impact on the economy. From an economic development standpoint, mobility and user cost measures are particularly salient, since they indicate the efficiency improvements of transportation infrastructure improvements to the electrical goods industry. Safety, environment considerations, and impact on the economy (i.e., jobs created) are broader social concerns that are factors in most transportation improvement decisions.

Step 4: Collect Data and Define Conditions for Specific Problems

This step focuses the investigation into the regions and highways that were selected in the problem identification step as being the most significant to the electrical goods industry. The FAC, particularly representatives from SIC 36 companies in the Richmond and Northern Virginia areas, would be useful in providing detailed descriptions and anecdotal accounts of SIC 36 goods movement in these areas. The MPOs for these areas should also be consulted.

The system inventory indicates that further data collection efforts should concentrate on I-95 (particularly around Richmond and Northern Virginia), I-81, I-64, I-66, and Route 29. Data requirements for performance measures include highway geometrics and operating characteristics, carrier operating costs, crash rates, emissions rates, and fuel consumption.

Step 5: Develop and Evaluate Improvement Alternatives

The FAC would play a major role in the development of improvement alternatives. Possible alternatives to improve Virginia's SIC 36 transportation include improving truck access to major manufacturing facilities and using intelligent transportation systems (ITS) to improve efficiency at truck weigh stations.

From a different standpoint, this would be the appropriate point in the freight planning methodology to investigate why other modes are not used to transport electrical goods. Consultations with the FAC might uncover reasons for this, such as distance; additional cost and time for intermodal transfer, and airport access problems. This could lead to more improvement alternatives, such as designated airport terminals, or more efficient goods handling by airport personnel.

The evaluation of the improvement alternatives should use the previously established performance measures. The capital cost of each improvement should be estimated, and possible funding sources investigated. Opportunities for private sector funding are promising in this case, since companies such as Motorola stand to benefit significantly from transportation improvements and could be willing to share the costs of implementation.

Step 6: Select and Implement Improvements

Improvements would be selected based on the evaluation of alternatives. The system inventory can be updated by including improvement alternatives where possible. This includes adding or modifying infrastructure elements in the system inventory and altering the impedance factors so they more accurately represent the likelihood that freight will be shipped between two regions.

DISCUSSION

For a more complete analysis of Virginia's overall goods movement, the system inventory procedure performed for SIC 36 could be replicated for other commodities. With the commodities that constitute the majority of the state's freight layered on top of each other, a realistic picture of statewide goods movement would be formed.

The case study also served to illustrate further the concerns about the availability and utility of freight data. The CFS is the most comprehensive publicly available compilation of freight flows, but it was not particularly user-friendly. To obtain data for Virginia as the state of destination, the CFS document of each origin state must be consulted. Like VEC employment data, the CFS is also subjected to some disclosure suppression, and some sampling variability, which affected the completeness of the data. Further, the CFS does not capture recent changes in goods movement, since the data are for 1993. However, the data disclosure did provide the opportunity to develop and test data gap-filling techniques that could prove to be useful skills in an environment of limited and questionable data. The gap-filling techniques provided reasonable results when compared to actual data and would be worthwhile for instances where no alternative data exist.

The distribution of SIC 36 goods movement was carried out in the case study using a gravity model. This technique does not account for the complex interaction between goods, which occurs in industry. For example, a facility in Lynchburg might manufacture electrical parts that are used exclusively as an input to production of another electrical product in Fairfax. However, this relationship would not be recognized by the gravity model, which would distribute most of Lynchburg's origin goods to other nearby counties. A more realistic distribution model would be based on input/output tables for the electrical goods industry. Alternatively, a model that distributes SIC 36 freight of lesser value to facilities manufacturing goods of higher value could be used. Unfortunately, these methods would be far more data intensive than a simple gravity model. Information such as the value or use of goods being produced at a facility is difficult to obtain.

CONCLUSIONS

- *There are significant differences between freight and passenger transportation that require different planning techniques.* These differences include:

  — Different modeling techniques are required for freight transportation.

  — Different performance measures are required for freight transportation.

  — Freight transportation planning covers a broad geographic area and is more logical at the statewide level than passenger transportation planning, which involves primarily local issues.

- *The use of a standard but flexible freight planning methodology is a worthwhile effort that can enhance future goods movement.* The benefits of using a standard methodology for freight planning are:
  - public and private communication on freight issues
  - consistency between different planning efforts throughout the state
  - increased interest and attention to freight issues.
- *The case study indicated the need for a GIS freight transportation database.* The manual assignment of freight flows to transportation routes was particularly tedious and awkward and would have benefited greatly if the network had been in GIS format.
- *Overall, the case study provided an effective demonstration of the freight planning methodology, particularly the system inventory.* The map of future SIC 36 freight flows throughout Virginia is valuable information to direct any decision on transportation improvements and how they might affect the electrical goods industry. Unfortunately, the lack of available freight flow data at sub-state levels makes it difficult to assess the accuracy of the freight flows modeled for the system inventory.

RECOMMENDATIONS

1. *TPD should use the methodology developed in this study to predict future goods movement and plan transportation infrastructure improvements*. The freight planning methodology can also provide valuable results that will lead to more informed infrastructure investment decisions. With continued use, the methodology would evolve and improve as the system inventory grows, more accurate indicators of production and attraction are discovered, and the movement of goods throughout the state becomes better understood

2. *TPD, in cooperation with the Virginia Department of Rail and Public Transportation and the Virginia Port Authority, should establish a Statewide Freight Advisory Council*. Input from the private sector is critical to effective freight planning, since they are intimately familiar with the freight transportation system from everyday use.

3. *TPD should incorporate a GIS freight transportation database into the freight planning methodology*. The freight planning methodology would be greatly enhanced if it were run on a GIS platform. The GIS would store and manage geographic and attribute information necessary for the system inventory and assist in freight modeling computations. The organization of data in GIS form would allow the effects of transportation infrastructure changes to be viewed quickly for a "what if" analysis.

4. *TPD should consider exploring options for purchasing freight flow data*. Several state DOTs and planning agencies have found private consultants to be reliable and accurate providers of

freight flow data. Although there is an initial cost involved, purchasing freight flow data could prove to be a more efficient of public sector planning resources. The data would be particularly useful for initial iterations of the system inventory, which is the most involved and time-consuming component of the freight planning methodology.

5. *TPD should continue to monitor advances in freight planning practices*. The freight planning efforts of other states should be continuously reviewed. In particular, CALTRANS is investing substantial resources to research freight planning. Available data sources should also be monitored, so that freight planning efforts can benefit from new, modified, or improved freight data. Finally, federal legislation should also be continuously reviewed with regard to regulations and guidelines concerning goods movement.

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