FINAL CONTRACT REPORT

RESEARCH NEEDS FOR DEVELOPING A COMMODITY-DRIVEN FREIGHT MODELING APPROACH

Kathryn L. Peacock
Graduate Research Assistant

Michael J. Demetsky, Ph.D., P.E.
Faculty Research Scientist
and
Professor of Civil Engineering

Project Manager
Michael A. Perfater, Virginia Transportation Research Council

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ABSTRACT

It is well known that better freight forecasting models and data are needed, but the literature does not clearly indicate which components of the modeling methodology are most in need of improvement, which is a critical need in an era of limited research budgets. This effort sought to identify those components using a logistics-driven approach as a starting point. The research began by examining other states' responses to freight planning legislation. A survey was sent to 47 states to determine the types of freight planning and freight modeling that occur and to understand the current data available and data needs. Research was conducted to gather information on how the supply chain functions and how logistics decisions regarding supply chain management are made. Sample supply chains were created for a variety of commodities, and mode choice was related to the behavioral aspects of the supply chain's logistics system. Once the mode was determined, the route assignment could be determined based on the accessible freight infrastructure.

It was found that not all elements of the freight modeling methodology are equally weak: indeed, trip attraction components for the production of raw materials and the dissemination of these materials from the manufacturing plant, whether to the consumer (in a traditional push system) or to a just-in-time distribution center (in the newer pull system) are adequately developed in practice. However, it is critical that future research address the following needs, listed in order of descending priority: (1) the mode choice component for delineating travel by air, truck, rail, water, or a combination thereof; (2) trip attraction equations for intermodal facilities that are used when manufacturing plants outsource key components rather than creating all components in-house, and (3) trip attraction equations for representing the flow of goods from distribution centers to the consumer.

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INTRODUCTION AND BACKGROUND

The Intermodal Surface Transportation Efficiency Act (ISTEA) and its reauthorization legislation, the Transportation Equity Act for the 21st Century (TEA-21), require transportation planners to consider the movement of freight and people in statewide and metropolitan area transportation plans. A six-step statewide intermodal freight transportation planning methodology was developed in 1998, providing a standard procedure for identifying current freight movement problems, anticipating future problems with the freight transportation system, and selecting and evaluating infrastructure improvements to facilitate freight movement in Virginia.[1]

The technical analysis for the planning methodology is mainly accomplished in the step entitled "Inventory of the System." The first task in the system inventory research at the Virginia Transportation Research Council (VTRC) was to define the existing freight transportation infrastructure for Virginia's highways, railways, and waterways. The *Transearch* commodity flow data were purchased by the Virginia Department of Transportation (VDOT) from Reebie and Associates and used to identify Virginia's 15 "key" commodities by the two-digit Standard Transportation Commodity Classification (STCC) code based on weight and value of the commodity (see Table 1 for a listing of the 15 key commodities). The State Freight Advisory Committee, a group of public and private sector stakeholders, convened and validated that the 15 commodities were the most prevalent commodities among the five modes for Virginia.[2]

Future freight flows were forecast using socioeconomic data.[2] Population and employment data were acquired for the year the *Transearch* data were collected (1998) for counties and cities in Virginia and used to predict freight attraction and generation equations.[2] In a subsequent project a gravity model was used to distribute truck freight flows at a county level using travel distance as the impedance to flow.[3] The results of the distribution analysis indicate that the four-step transportation planning process as used for person travel is unlikely to be directly applicable to freight transport. This is because the modal split used prior to trip distribution that was assumed to not change from the base year to the forecast year, thus

Table 1. Virginia's Key Commodities[2]

STCC	Commodity
3700	Transportation Equipment
2800	Chemicals or Allied Products
3600	Electrical Machinery, Equipment or Supplies
3500	Machinery, excluding Electrical
2000	Food and Kindred Products
2600	Pulp, Paper, or Allied Products
3000	Rubber or Miscellaneous Plastic Products
3200	Clay, Concrete, Glass or Stone Products
2400	Lumber or Wood Products, excluding Furniture
1100	Coal
1400	Non-metallic Ores and Minerals, excluding Fuels
2300	Apparel or Other Finished Textile Products or Knits
2100	Tobacco Products, excluding Insecticides
2700	Printed Matter
2900	Petroleum or Coal Products

trivializing the modal choice decision. The estimation of freight generation and attraction appears to be valid and justifiable as the first step in the forecasting process, but the modal choice decision needs to be reconsidered before origin-destination (O-D) flows can be forecast.[3] The modal choice component is relevant to the trip attraction equations in practice; thus key commodity data that are more detailed than are currently used are needed to provide a greater understanding behind the decisions underlying the generation, attraction, distribution, mode choice, and route assignment of freight commodity analysis.

PURPOSE AND SCOPE

This project investigated commodities relative to their industry at a four-digit STCC code level. Based on the characteristics and flow trends identified, suggestions were made as to how to create a behaviorally based method to replicate and forecast freight movements. In order to facilitate this investigation, the logistics behind production, transport, and warehousing of these commodities was researched. It was envisioned that the results accomplished at this point will identify characteristic flow stages and patterns for selected commodities, which will then aid in model development and parameter estimation.

The research findings are interpreted to provide a direction and procedure for state and metropolitan transportation planners to develop a complete set of integrated freight forecasting models. The planning procedure will provide the means to identify and plan for improvements to the infrastructure system to allow for more efficient freight flow throughout Virginia.

METHODS

The framework for a logistics-based statewide freight transportation planning process was developed by performing the following tasks.

1. *Conduct a literature review and survey of state DOTs.* A literature review was conducted to determine the state of the practice of modeling freight flows and traffic from a statewide perspective. In addition, the level of detail in freight flow data that other states have available and the sources of such data were assessed through a state freight flow survey. The surveys also sought information about the type of freight planning that is being conducted and the type of data collection, modeling techniques, and data supplementation methods that are being used.

2. *Investigate the supply chain.* The components of the supply chain were defined, and the logistics decisions behind supply chain decisions were investigated. A general chart was created illustrating product flow through the supply chain.

3. *Establish commodity specific flow characteristics.* A micro-investigation of certain key commodities at the four-digit STCC level was conducted to identify specific production/distribution characteristics of those commodities.

4. *Hypothesize modeling strategies/frameworks.* Strategies were defined for creating a model of freight movement based on the characteristics of the commodity, industry, and appropriate shippers.

RESULTS AND DISCUSSION

Literature Review

A literature review dating back to 1990 on statewide freight transportation planning procedures was performed using the Transportation Research Board's TRIS search and selected Internet sites. States that have produced models depicting freight flows have typically done so in a similar manner using the traditional four-step urban transportation planning model. That is, the existing transportation infrastructure is inventoried from various maps and databases for freight moving by truck, rail and water. The locations of intermodal hubs and airports are sometimes recorded as well. Current freight movements are then entered from sources such as the Commodity Flow Survey (CFS), the Census of Agriculture, and the *Transearch* database.

Commodity flows are represented as tonnage, value, or a combination of these two measures. Generation and attraction equations are employed for selected commodities based on socioeconomic data acquired from a variety of sources including IMPLAN and the U.S. Census Bureau. Finally, distribution is determined using the gravity model or a similar model, but typically only for the truck mode using an impedance of travel time or distance. Modal choice was also determined in some states. In Iowa, for example, the modal split was determined by subtracting rail tonnage from total tonnage resulting in truck tonnage.[4]

Researched models that have not been applied by the states that were found and deemed appropriate for this research were disaggregate models that were either inventory or behaviorally based.[5] The inventory based models take into account behavioral considerations but analyze the freight travel demand from the perspective of the inventory manager.[5] The inventory approach attempts to integrate the mode choice and production decisions made by a firm.[6] The behavioral models explain freight travel demand by utility maximization made by a known decision-maker such as a supply chain manager.[5] The behavioral disaggregate demand models focus on mode choice based on microeconomic theories of behavior.[6] A combination of these two approaches is potentially appropriate for freight movement represented here from the perspective of the best use for the supply chain as a whole, integrating the idea of holistic freight management that benefits the entire supply chain, not just one tier of the supply chain, as suggested by the inventory manager approach. As has been stated: "Freight demand models should consider not only the two primary actors, the shipper and carrier, but also the chain of intermediaries that are more involved in the distribution business."[5]

The statewide freight transportation modeling process and planning conducted in other states have limitations. The most notable limitation is the lack of publicly available detailed data upon which to base the models. Specific data are needed to answer planning questions that involve identification of problem areas or sections of major freight routes. Private companies are reluctant to share their information because the data are proprietary and they believe that sharing it could lead to that company having a competitive disadvantage.

Another limitation to state modeling efforts is the lack of data for conversion of tonnage, the unit used in the CFS and the *Transearch* database, for trips such as truck or rail. Some states have done this step using conversion tables, the Consumer Price Index, or the Vehicle Inventory and Use Survey, but the degree to which each truck is loaded is changing due to the increasing popularity of just-in-time (JIT) delivery that promotes smaller shipment sizes.[7] Additionally, globalization is resulting in longer truck trips, which vary in shipment size. In fact: "The globalization of business has increased the need for global supply chains that are longer, more complex, and inherently costlier"[8] The development of global economies will also lead to increased use of global third-party logistics providers (TPLP) to provide logistical services.

The last limitation involves the method that some states use to respond to freight flow barriers. As has been stated: "Planning still takes place mostly at the modal level, and statewide plans often are a compilation of modal plans rather than a series of multimodal and intermodal solutions to identify needs."[9] Determining current problems through roadside surveys, trucker interviews, and committee meetings where the private sector voices problems with the current infrastructure are reactive approaches to alleviating stress on the freight infrastructure. The ISTEA and TEA-21 legislation provides that states take a proactive approach to freight planning, rather than the reactive approaches that are currently the practice.

State Freight Survey

A survey was developed and distributed to the office responsible for freight planning at 47 state DOTs to determine if any was conducting supply chain research. Twenty-five were completed and returned, yielding a response rate higher than 50 percent. The state contacts are listed in the Appendix.

The survey asked participants whether freight studies have been conducted in their state since ISTEA became law in 1991. The question was intended to gather information on new ideas investigated in recent years. It was found that Kentucky has created an “Intermodal Facility Directory” that is updated every 2 years. This database is useful in researching other modes besides truck for movement to and from intermodal hubs.

Survey results confirmed that other states implement freight planning strategies similar to those in Virginia. For instance, eight states (Colorado, Delaware, Connecticut, Kentucky, Maine, South Carolina, South Dakota, and Tennessee) in addition to Virginia have conducted studies evaluating the access and mobility options with regard to freight infrastructure. A commodity-based analysis had been performed in a number of states, similar to that performed at VTRC.

Freight Planning Data

One set of questions used in the survey focused on the freight planning data that are collected and used. First, the states were asked whether or not freight data were collected and, if so, whether the data were collected at the commodity level, or the vehicle level. If data were collected at another level respondents were asked to specify what the level was.

Data collected at the commodity level must first be converted to the vehicle level. This conversion is difficult because of the changing nature of the types of shipments in terms of load size and frequency. To resolve this issue, in cases where the state responded that their data were collected at the commodity level and then converted to the vehicle level, their conversion was analyzed for its applicability in Virginia. Similarly for states responding that the data were collected at the vehicle level, the method of collection was also investigated for possible use in Virginia.

Sixty percent of the responses indicated that their state collects and/or uses freight data. Some collect data for all modes, while others concentrate on one or more modes of transport. For example, Arkansas collects data for all modes while Colorado collects only truck data. The level at which each reporting state collects and uses its data, as well as the respective modes, is summarized in Table 2. Note that only 14 states as shown in Table 2 provided the information of data collection in the survey. Virginia does not collect any freight data. The states that collect individual truck vehicle data do so by conducting roadside surveys or individual truck counts, this is usually limited to smaller areas. This method is not feasible in Virginia due to its large size.

Table 2. Responses to Data Collected and Used for Freight Planning

State (Mode)	Collected		Used	
	Commodity	Vehicle	Commodity	Vehicle
Arkansas (all)	✓	✓		
Colorado (truck)		✓		✓
Connecticut (all)	✓		✓	
Delaware (truck, rail and water)	✓			✓
Iowa (rail and water)	✓		✓	
Kentucky (all)	✓	✓		✓
Maine (all)	✓		✓	
Minnesota (all)	✓	✓	✓	✓
New York (all)	✓	✓	✓	✓
North Dakota (all)	✓			
Oregon (truck)	✓	✓	✓	✓
Pennsylvania (truck and rail)		✓		✓
South Dakota (rail)	✓	✓	✓	✓
Washington (truck and rail)	✓	✓	✓	✓
Wyoming (truck)		✓		

Another set of survey questions was intended to determine whether the *Transearch* data were used and how these data were supplemented. If a source for commodity flow data other than *Transearch* was used, that source was noted. This part of the survey also sought to determine ways in which other states accounted for empty truck trips.

Roughly 40 percent of the responding states used the *Transearch* data. Most data collection efforts appeared to include the *Transearch* data, the CFS data, or the Rail Waybill data. Basically, *Transearch*, a unified, multimodal goods movement database that includes tonnage and equipment volumes by commodity, transportation mode, and lane. CFS data are information on shipments by domestic establishments in manufacturing, wholesale, mining, and selected other industries. Rail Waybill data are shipment data from a stratified sample of rail waybills that contain origins and destination points, types of commodity, number of cars, tons, revenue, length of haul, participating railroads, and interchange locations. Detailed information about these three data sets can be found in Brogan et al.[2]

Other sources used to supplement these primary sources include surveys, interviews, and traffic counts. However, these sources were useful only when the area studied was very small. In these cases one-on-one interviews in the form of roadside surveys, phone interviews, or actual traffic counts were used to acquire the level of detail necessary to compile a useful model. Typically, states used freight data to solve problems in metropolitan areas or at intermodal terminals. Of those states with data collection methods, only 30 percent are using them for modeling purposes.

Survey results revealed inconsistencies among states regarding the reporting of empty truck trips. Delaware accounts for empty truck trips by calculating a flat percentage of return trips. Another and more appropriate method for counting empty truck trips is counting them at weigh stations, which is the practice in Washington. Wyoming accounts for empty truck trips from weigh-in-motion (WIM) data, a method that has also been proposed for Virginia. Although this method does not account for commodities, using WIM data can be useful in identifying major truck routes by direction. This method would alleviate the problem of identifying the direction that trucks are flowing using the *Transearch* data.[10]

Modeling and Forecasting

A section of the survey on modeling and forecasting techniques was designed to determine the modeling approaches employed by states. The need exists to determine the requirements of a model that could provide an improved method for forecasting freight or vehicle movement for strategic planning purposes.

None of the responding states that are performing modeling reported modeling freight based on the supply chain logistical approach. This finding implies that the approach for freight planning envisioned in this research represents a new technique for modeling freight movements at the state level. The majority of the states that include freight in their state transportation planning models typically used the four-step urban planning model framework.

The four-step urban planning model has proven inappropriate in previous research in modeling freight planning decisions because of the innate differences between passenger vehicle and freight travel.[3] For example, there is an average number of people per car that can be found to provide an easy conversion between volume of people and number of passenger cars for auto trip forecasting. No such associated value for freight exists. Therefore, a methodology to convert volume of commodity to number of trucks is needed.

State responses concerning the data for a better freight planning model followed a trend of needing O-D data about individual truck trips. South Carolina commented: "Better information about ultimate destination for port containers is needed." The supply chain research attempts to respond to these problems by determining origin and final destination, which incorporates the intermodal hub as an intermediate destination. Delaware, Kentucky and North Carolina stated the need for simple trip diary type information indicating origin, final destination, and route. New technology that is becoming available may make acquiring this type of data more feasible in the future. Once these data are acquired, modal shifts and intermodal terminal location can be determined.

Summary

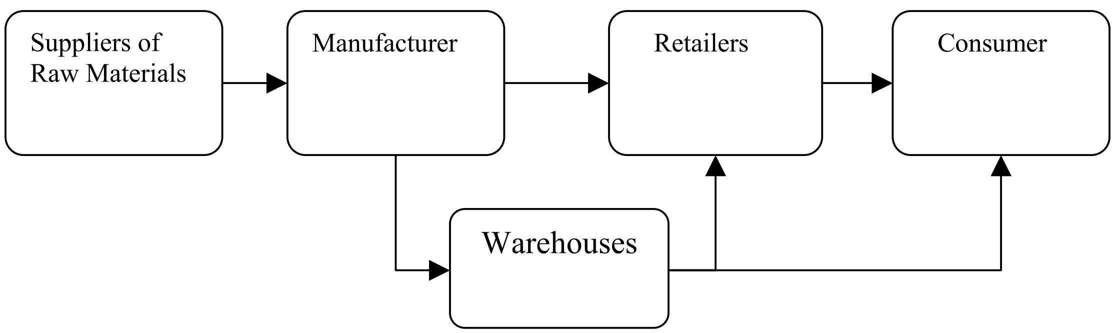
The survey revealed that states are complying with ISTEA and TEA-21 legislation regarding freight planning. The first step toward compliance involves incorporating freight into the transportation plan at the statewide, regional, and local levels. Data collection would include either compiling publicly available data, buying privately collected data, or conducting surveys to gather more detailed data. Some states have opted to use the four-step urban planning model for freight planning. No state reported being completely satisfied with the model results or with the data that were being collected; however, most states reported that they were in the process of developing new models and data sources.

Supply Chain Concepts

The supply chain is defined as the network of raw material suppliers, manufacturers, wholesalers, retailers, and transporters that participate in the production, delivery, and sale of a particular product. The manufacturer converts raw materials and component parts into a product at the production site. Manufacturers can sell their products in individual quantities to consumers, to the retailers, or, in larger quantities, to wholesalers who act as a warehouse or storage area for products not currently demanded by the market. The wholesaler can then sell its stored goods to retailers for resale or directly to consumers, depending on the supply chain relationship.

Transporters distribute the raw materials, component parts and final products to each point in the supply chain.[12] A general chart depicting the flow of goods through the supply chain is pictured in Figure 1. The arrows represent points of transport that occur by truck, train, plane, or ship that need to be tracked.

Figure 1. Flow of Goods Through the Supply Chain



It has been stated that: "Intermodal transportation is the most cost effective and efficient option for certain types of traffic-principally, regularly scheduled replenishment products moving long distances from manufacturing plants to distribution centers or wholesalers"[13] Using a wholesaler is valuable to the retailer in terms of transportation costs saved from receiving one large shipment from the wholesaler versus multiple smaller shipments from various manufacturers. A wholesaler also helps to ensure that stock outs do not occur by housing a large quantity of a variety of goods readily available for fast shipment. However, because the wholesaler collects profits for storing materials, additional costs are incurred by the retailer and thus the customer in adding this additional link to the supply chain. Therefore as part of the logistical analysis, the retailer must determine if it is more profitable to not use a wholesaler but risk the loss of customers due to stock outs, or if it is worth the extra costs to use a wholesaler to ensure customer service.[14]

A consumer can buy its goods from a variety of sources depending on the consumer's desired convenience, reliability and expense. The least expensive supply chain component to buy from is directly from the manufacturer. However, if the demand of the consumer is not known to the manufacturer, the product might not be available. Additionally, the location of the manufacturer could be very distant and inconvenient. A more convenient and reliable source are the retailers, which are much more plentiful and therefore tend to be more convenient, but often at an increase in cost. Generally there will be plenty of stock at the retailer, but if a large unforeseen demand for a product occurs there is a risk of stock outage. The warehouse is intermediate in terms of cost and convenience, but is the most reliable of the components due to the large stock held.[15]

The supply chain can be very complex with multiple possible flows depending on the characteristics of the product. A better understanding of the transportation needs associated with a product can be determined by understanding the characteristics of the commodity. Once these logistical transportation needs can be assigned to a product, the modal options, route and destinations for consolidation can be identified.

Supply Chain Management

Supply chain management is the oversight of materials, information and finances as they move along the supply chain from raw material to consumer.[11] Supply chain management has been used by many companies to increase organizational effectiveness and achieve organizational goals such as improved customer value, better utilization of resources, and increased profitability.[16] Companies are realizing that in order to develop or maintain a competitive advantage, effective supply chain management must be used to oversee the production of a product and ensure that the right product gets to the right destination, in the right quantity, with the right quality, at the right cost.[17]

Logistics is defined as the management of business operations, such as the acquisition, storage, transportation, and delivery of goods along the supply chain.[11] It focuses only on physical arrangement of goods (acquisition, storage, transportation, and delivery) and is thus a subset of supply chain management (which also includes the flow of information and finances). In order to accurately model freight movement, an understanding of the reasoning behind each step in the supply chain, and the logistical decisions that were made regarding that step is required. Once the logistical decisions for the supply chain are understood, the time constraints on the delivery of the product can be determined, and mode or intermodal options can be evaluated for freight planning purposes. Additionally, understanding the size and frequency of shipments will aid freight planners in determining the volume to vehicle conversions for each commodity.

Customer service involves the speed of delivery and quality of product being delivered to the customer. The transportation needs of a company are determined by the logistical decisions regarding the flow of the supply chain.[12]

Capital cost reduction involves a variety of decisions associated with the different components of the supply chain. Production decisions include where production should occur, whether to make the component pieces in-house or to buy them from external sources and the desired capacity of the manufacturing facility. Sourcing decisions involve the selection of suppliers who are in the right location and can produce the right quality of product in the right quantity. The decision to stock inventory or to have supplies and products delivered JIT is critical to the transportation decisions that need to be made. It has been said that: "Electronic commerce probably will bring about changes in both the configuration and profitability of a portion of the freight sector. It also might lead to reductions in average shipment size, corresponding increases in shipment frequency, and an emphasis on on-time delivery."[18] With the growth of e-commerce, the focus on reliable transportation will increase in order to keep costs low by not maintaining inventory, and also by promoting customer service through quick product delivery.

Last, operating costs include costs related to maintaining facilities and transportation costs.[19] Transportation costs include decisions regarding mode that are affected by speed and quality of the delivery needed based on the characteristics of the commodity. The facilities to be maintained include warehouses and intermodal facilities for consolidation. Over time with changing demands, the role of these facilities is changing. By understanding these changes, modal choice, shipment size and shipment frequency can be better understood; thereby enabling trip chains to be identified and a logistics based analysis of commodity movement to be performed.

Logistics Systems

Supply chain management for a "pull" system exists to provide coordination and integration between the various functions of the supply chain. However, in a "push" logistics system, information sharing does not occur to allow optimization of the entire supply chain. In a push logistics system the manufacturer decides what, how many, when and where to move products through the supply chain, based on historical data. It is referred to as a push logistics system because products are pushed through the supply chain by the manufacturer.[23] In general, the push system was more likely to result when organizationally the different elements of the supply chain are in competition with each other without information sharing; the pull system results when someone can exert a command-and-control influence, such as a TPLP.

Management occurs in a push logistics system at each component of the supply chain, rather than for the supply chain as a whole in a hierarchal fashion. As has been said: "These push logistics systems, inventory based models, presume that production is scheduled based on forecasted demand, and retail or industrial deliveries are made from pre-manufactured inventory."[20] Eventually, demand decreases cause an increase in inventory at the retailers, resulting in a decrease in orders to the manufacturer. Consequently, manufacturers will either stop production, causing a loss in jobs and an increase in raw materials inventory, or will continue to produce items that might not be sold. This requires holding the excess inventory in the warehouse, costing the manufacturer additional revenues, in turn driving up prices for the customer. This process is known as the *bullwhip effect*, which results when one portion of the supply chain is functioning with its advantage in mind, not the benefit of the overall supply chain. The push logistics system is wasteful of inventory and costly for production. This can be avoided by managing supply from a holistic viewpoint through a pull logistics system.

In a pull logistics system, each lower-level facility controls the flow of products through the supply chain by ordering the quantity needed based on real time buyer tendencies. A pull logistics system almost always eliminates the need for a wholesaler by selling directly to the retailer or consumer since demand is known and excess supply does not need to be stored. "A pull logistics system results in improved customer service with reduced inventory."[20] The pull logistics system relies heavily on horizontal supply chain management with information flowing freely between all members of the supply chain. "Supply chain management is beneficial because it reduces the magnitude and frequency of dramatic fluctuations in manufacturing. In turn, this results in increased profits and lower prices for customers by standardizing and simplifying the routine operations of the supply chain operations thereby promoting efficiency and effectiveness."[14] In order for this type of system to succeed, on-time, reliable transportation, otherwise known as JIT delivery, needs to be easily accessible. Also, timely access to accurate point-of-sale transaction information is required to match transportation needs with the supply and demand.

Transportation needs increase dramatically with a pull" logistics system in order to transport the product from the production site to the retailer or consumer in a timely fashion. "'Pull' logistics systems, replenishment-based models, suggest that product manufacturing is coordinated to actual point-of-sale transactions, and that re-supply is made directly from the production site."[14] JIT delivery replaces inventory as soon as the inventory runs out in stores, thereby meeting the needs of the customer without carrying the expense of excess inventory. JIT delivery for the pull logistics system results in stock being held in transport rather than being held in a warehouse, consequently, smaller, but more frequent shipments are made.

Large trucks with small shipments are costlier to the shipper due to the loss of revenue in wasted space on each truck. Relatively, the costs for trucks and operations costs for truck drivers (due to long distance travels) are higher than those in a transit system, which makes the loss of revenue in wasted space on each truck is more severe.

Longer distances with small shipments should be consolidated on larger trucks at intermodal hubs to save time, money, and space. Smaller shipments that travel in larger loads for long distances are more cost efficient then small shipments in small trucks for the same long distances. Coordinating this activity can be achieved with a pull logistics system but requires a large degree of information sharing between the manufacturer, retailer and wholesaler to meet the needs of the consumer.

Information Sharing

The pull logistics system transforms the supply chain from working as a part-by-part system to functioning as a whole entity, and sees the supply chain as a horizontal structure with information flowing freely between each supply chain component. Information sharing is required for the supply chain components to perform with full coordination in this horizontal manner. As has been said: "Information sharing describes the extent to which one party in the chain communicates critical and proprietary information to another party in the chain."[17] Each supply chain component needs to communicate with the other components so that the supply chain works as a horizontal structure rather than a vertical, hierarchical structure.

Certain fundamental operational information such as production schedules, delivery schedules and order status must be shared in real time in order for supply chain components to achieve system coordination. Sharing of production schedule and order status information allows the retailer or the customer to be informed of the progress of shipment of the product, improving customer service. Combining production schedule information with delivery schedule and order status allows less than truckload shipments to be combined to fill the truck reducing operations costs.

Information sharing is difficult for companies to accept and put into practice because it means that they must relinquish total control of information amongst its components. As has been said: "True supply chain management partners understand that they must equally share in the risks and rewards."[17] Retailers risk stock outs, manufacturers risk too much or too little production and that could result in the loss of a customer. Further: "The manufacturers and retailers we interviewed believed that replenishment-based logistics systems offered efficiency versus traditional inventory-based models, but were reluctant to risk the increased stock outs perceived to accompany replenishment models."[20] Consequently, many companies relinquish only partial control of their components to other divisions within the company or to other companies. However, this does not result in an efficient supply chain. To combat this predicament, many companies turn to TPLP to handle information sharing.

Third-Party Logistics Provider

TPLPs own the market niche in information sharing. The TPLP collects information at all levels of the supply chain and uses that information to operate more efficiently without sharing proprietary information across the components of the supply chain. In essence, the TPLP acts as the supply chain management for the company making decisions regarding location, production, inventory and transportation for the company. The information collected is most frequently used to handle transportation issues such as mode of transport, routing choices, and consolidation of shipments.

As has been said: "The disadvantages identified to occur with the use of a third-party-logistics provider include loss of control, increased uncertainties and cost concerns."[17] Logistics partnerships fail because of a lack of mutual understanding between parties, over-promising, poor communication, and lack of top management support. Therefore most companies are still reluctant to switch to the use of the TPLP despite the virtues that have been observed. The largest and most pronounced benefits have been incurred by only a select number of companies because companies believe that they can slowly venture into a pull logistics system instead of diving into the commitment.

TPLPs develop their shipping strategies based on a number of factors. The goals of the company that is outsourcing its shipping decisions are discussed with the TPLP. Oftentimes these goals include shipment timeliness, quality of shipment in terms of minimizing damage during transit, cost of shipment, and customer service. The TPLP determines all the available routes, modal choices (including intermodal options) and consolidation points for same mode shipments from the origin to the destination. Each feasible option is evaluated based on the goals of the company and the shipping strategy that is best suited to meet the goals of the company is chosen.

Summary

Supply chain management was once a system based on historical sales (a push logistics system) but is changing to a system based on current replenishment needs (a pull logistics system). The emergence of TPLPs has made this transition possible by promoting information sharing but by also safeguarding their information so that the competitive advantage remains with the company with which it was developed.

Volume-to-vehicle conversions are needed to assign tonnage to individual shipments in the freight planning process. Traditionally these conversions are made based on historical data, but with the changing supply chain from a push logistics system to a pull logistics system, these conversions are no longer valid. Shipments that are part of a supply chain that uses the pull logistics system are much smaller but more frequent. The old conversions that are typically used to forecast freight flow underestimate the actual number of vehicles on the road so an updated conversion system must be used to account for freight flow. By understanding the supply chain characteristics, trip chains can be developed that link the final product to the intermediary flows that lead to shipment conversions.

Case Study: STCC 3600 Electrical and Electronic Equipment

Introduction

Deciding upon a transportation mode for some commodities, such as coal, which travels by train due to its high weight and low cost, is a clear-cut process. In many other cases transportation decisions are more complex. Here commodities are typically high in value and low in weight with final product costs that are highly dependent on unused inventory and transportation related costs. Conversion charts used to convert volume-to-vehicle values have been used based on historical data for all commodities at the two-digit level. Brogan et al.[2] recognized that a change in the degree to which each commodity was loaded was only recognizable at the four-digit level for some commodities and recommended that certain commodities be broken down to the four-digit level in future analysis.[2]

Accompanying the change in shipment characteristics for certain four-digit commodities that have migrated to the pull logistics system, is the presence of commodities that originate or terminate at a warehouse, distribution center or intermodal terminal in the *Transearch* data that are described as "intermodal shipments."

> Traffic movements originating in warehouses or distribution centers are shown as commodity code 5010. These are by definition truck movements. Movements to warehousing and

> distribution centers may be by other STCC codes and by any mode. Details on the types of items being moved are not available. This is also true for the truck portion of rail/truck intermodal activity (Code 5030) and the drayage of air freight activity (Code 5030).[21]

One objective when developing supply chain case studies for the specific commodities is to develop trip chains that link "intermodal" shipments to the product and the demand for the product. Complete supply chain flows are needed to track the product from origin to destination including the location and identification of the intermodal terminals. Creating these trip chains will enable more accurate generation and attraction equation development for the "intermodal" shipments.

All 15 key commodities need to be disaggregated at the four-digit STCC level. Based on recommendations from previous research, a sample supply chain model was investigated for commodities with STCC codes 3500, 3600 and 3700.[2] Once these supply chains are understood, trip chains can be identified that will lead to a better understanding of modal split and route assignments based on shipment characteristics. Knowing the supply chain from the private sector perspective will lead to more accurate volume-to-vehicle conversions for the public sector, especially for those commodities whose four-digit STCC commodities have changed. Last, assigning a product to the "intermodal shipments" used in the *Transearch* data will be possible only with the identification of trip chains. As an illustration of a detailed case study analysis, the supply chain for electrical and electronic equipment, STCC 3600, was examined.

Case Study

STCC code 3600 is categorized as electrical and electronic equipment. The sub-commodities in that commodity grouping are listed in Table 3.

Bruce Isaacson with Professor Roy Shapiro at the Harvard Business School prepared the Bose Corporation case study. The Bose Corporation manufactures speakers for home and car use, which falls under the sub-commodity category of household audio and video equipment in STCC code 3651.[22] The headquarters of the company is in Framingham, Massachusetts.

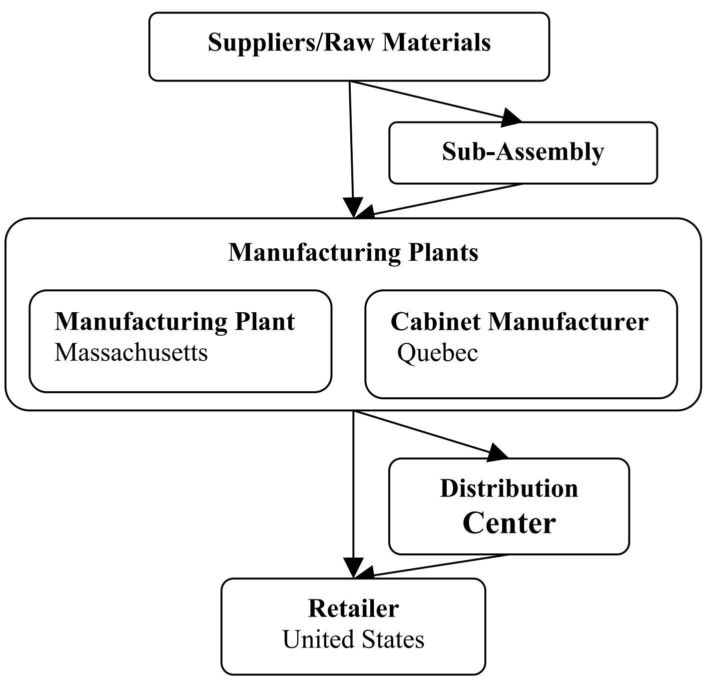
A sample of the supply chain can be seen in Figure 2. As has been said: "The supplier provides the raw materials to produce the speaker either to the manufacturing plants who can produce the speaker part entirely at the facility or to the sub-assembly vendor who produces components of the speaker to be resold to the manufacturing plant to simplify the manufacturing process. Speakers are composed of three major parts: the transducers responsible for sound production, the electronics which compose the circuit boards and the cabinet which is the speaker's exterior."[23] These shipments from the raw materials supplier to the manufacturing center are listed as intermodal in the Reebie *Transearch* data.

Two manufacturing plants, located in Massachusetts and Canada, serve the United States markets. The Massachusetts manufacturing plant produces all components of the speaker except the cabinet and assembles the components on-site. The Quebec plant specializes in manufacturing cabinets for the speakers and ships them primarily to the Massachusetts location. Cabinet production and finished cabinets consume the most space in comparison with the

Table 3. STCC 3600 Electrical and Electronic Equipment[22]

4-Digit STCC Code	Sub-commodity
3612	Power, Distribution, and Specialty
3613	Switchboard Apparatus
3621	Motors and Generators
3629	Electrical Industry Apparatus
3631	Household Cooking Appliances
3632	Household Refrigerators
3633	Household Laundry Equipment
3634	Household Electric Equipment
3635	Household Vacuum Cleaners
3639	Household Appliances
3641	Electric Lamps/Lighting Fixtures
3643	Outlets/Switches/Wires
3644	Non-current Carrying Wiring Devices
3651	Household Audio and Video Equipment TV's/Radios
3652	Phonograph
3661	Telephone and Telegraph Apparatus
3669	Communications Equipment
3691	Storage Batteries
3692	Primary Batteries, Dry and Wet

Figure 2. Bose Sample Supply Chain



component parts. The Massachusetts manufacturing plant stores the smaller quantity of cabinets to save spatial costs, but requires frequent, reliable shipments. Since truck is the most reliable mode of transport, it is used for these shipments; stock outs of cabinets would result in a halt in production costing more money then stocking the bare minimum number of cabinets.

A vendor representative for a company that performs sub-assembly work for Bose is located in the Bose manufacturing plant in Massachusetts. This person replaces the vendor salesperson (a Bose buyer) and the Bose materials planner. The vendor representative works full-time in Bose but is paid by the vendor and officially works for the vendor. The advantage for Bose is that the vendor has real time information and can therefore order shipments accordingly resulting in less inventory and larger loads per shipment. The vendor benefits by having an in-house representative thereby guaranteeing sales. Due to the need for reliable transportation to prevent stockouts a true pull logistics system cannot be used, but this adaptation to JIT delivery has been used by Bose and is called JIT II.

A total of six products, as summarized in Table 4, were investigated in this study at the four-digit STCC code level to determine trip chains from the origin of the raw materials to the delivery of the final product to the consumer. All the major points in the supply chain were identified and the functions performed at each destination where the product was changed were examined. These origin-to-destination trip chains connected the subcomponents of the product at the four-digit STCC code level to the final product. Those commodities traveling by modes indicated as "intermodal" in the *Transearch* database are often the subcomponents of the product that do not have associated generation, attraction, mode, and route choice attached. By linking the subcomponents to the product through trip chains, then the chained equations for the product can be established. For example, sunroofs are classified in the Reebie data as traveling by "intermodal" mode because they are shipped to a warehouse or consolidation point under the producer of the sunroofs ownership and then change ownership to the car manufacturer when they arrive in the manufacturing plant for the car. Generation, attraction, modal choice and route choice can be linked to the sunroof through demand for the car. Table 4 summarizes the links of the supply chains used for each of the six commodities reviewed.

Once the characteristics of the supply chain are understood then time urgency can be determined for delivery of the raw materials and for delivery of the final product. Time constraints determine the modal choice of a commodity and its sub-commodities and the degree to which each vehicle is loaded.

Table 4. Summary of Supply Chain Links for Each Case Study

STCC Code – Company	Raw Materials	Intermodal Terminal	Manufacturer	Distribution Center	Retailer
3500 – Deere	X		X		X
3600 – GA Company	X	X	X	X	X
3600 – Bose	X	X	X	X	X
3600 – Apple	X	X	X	X	
3700 – Saturn	X		X		X
3700 – BMW	X		X	X	X

Summary

Case studies are a useful way to understand the logistical decision making process from the private sector point of view. Such findings are used to link the private sector logistics process approach to the public sector freight planning approach, thereby providing a link between the supply chain and its logistical characteristics and developing freight flows and trip chains, volume-to vehicle conversions, modal split, and route choice.

ANALYSIS: A PROPOSAL TO DEVELOP COMMODITY-DRIVEN MODELING STRATEGIES

Modeling Strategies

Here ways to interweave the stages of the supply chain with public sector freight planning are investigated. This approach takes the four-step model and uses the behavioral characteristics of the freight supply chain to replicate freight movement, thereby interweaving the public and private sector methods to develop a complete model for freight movement.

Based on the information collected on the supply chain, its characteristics and the case studies examined, it was shown that the model must be able to account for a variety of situations that are not examined in the four-step urban planning model. The primary task is accounting for modal split and the change in modal split that is occurring with the changing supply chain. Accompanying the change in the way that the supply chain functions is a reduction in the size of shipments that must be reflected in the model. Traditionally volume-to-vehicle conversions have been based on historical data, however with the change in shipment size comes a change in the volume-to-vehicle conversions that are typically used. Last, the model should be able to identify trip chains, thereby linking the generation and attraction equations developed for the final products to those shipments that incur transfers at intermodal terminals, and therefore are not linked to any attraction or generation in the *Transearch* data.

Figure 3 shows the recommended methodology. The first step is to develop generation and attraction equations for products based on the *Transearch* data as performed by Brogan et al.[2] Production characteristics for each four-digit STCC code would be established and then the supply chains specified. Trip chains would then be developed linking subcomponents to the final product. Modal trip distributions would be completed for each commodity based on these trip chains characteristics and the associated logistics. Additionally, by understanding the supply chain, more accurate volume-to-vehicle conversions can take place based on current data that incorporate the pull logistics system. Last, route assignment would occur based on the available infrastructure for the mode chosen.

Figure 3. Methodology for Freight Planning

Methodology
1) Trip Generation and Attraction – Brogan et al.[2]
2) Determine productions for specific supply chain characteristics per commodity type
3) Determine Trip Chains
4) Take findings from 1,2 and 3 and do modal trip distributions – Mao[3]
5) Determine Vehicle Trips
6) Perform Route Assignments

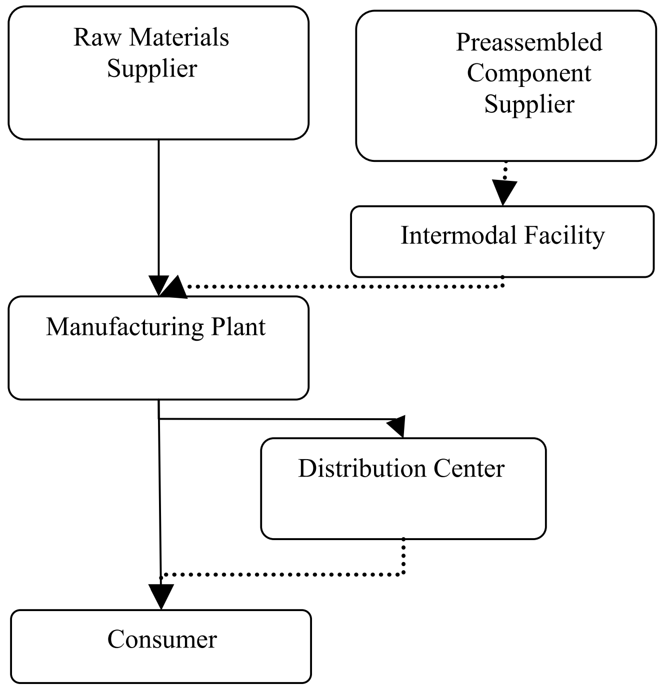
Modeling Example

The Bose case study is an example of how the modeling strategy can be implemented. The first step is to estimate generation and attraction equations for the product, which are speakers in the case of the Bose Corporation. The speaker, STCC code 3651, represents three major parts, the transducer, the electronics and the cabinet. The cabinet is manufactured in Canada and shipped to the Massachusetts plant for final assembly. All other components are produced at the Massachusetts plant. Minimal inventory of cabinets is stored in the Massachusetts plant due to the large spatial requirements of the cabinets.

The cabinet shipment is listed in the *Transearch* data as traveling by intermodal means because it is shipped to Massachusetts by truck and can depart the plant by a different mode of transport. The cabinet to the Massachusetts plant represents the identified trip chain, where the rest of the speaker is produced. There, the final speaker is made and sent to the consumer. The demand for the speaker can therefore be linked to the demand for the cabinet, associating the speaker's generation and attraction equations with that of the cabinet that is used to produce the speaker. The modal choices for the speaker are either by truck, train or airplane, and the route can be assigned based on the availability of the infrastructure. Due to the large size of the cabinets, frequent shipments in small numbers are made to the Massachusetts plant from Canada. This provides insight into the volume-to-vehicle conversions, and illustrates the fact that the shipment size is shrinking and therefore the historical values are not accurate for STCC code 3651.

Figure 4 examines the supply chain flow and identifies where additional data are needed and where the redeveloped freight modeling techniques are deployed. The dashed arrows represent areas where new modeling techniques are needed. The solid lines represent where the *Transearch* database provides adequate detail. The *Transearch* data are valid for flows where the product has undergone final assembly, however, for flows where parts are preassembled or for pieces that spend time in an intermodal terminal under the producing part's company, the attraction equations do not exist. By developing an understanding for the supply chain, the trip chains that link attractions for the preassembled and intermodal components to the attraction of the final product, can be identified. Planners can use these data for determining distribution patterns and current modal split.

Figure 4. Freight Flow Process



Further Study Plan

As described in the modeling strategies, identification of supply chains will be the basis for developing improved models for freight planning, especially for the trip destination and mode choice components. Thus, the first step is to identify supply chains for the key commodities in Virginia. In the second step, data to develop trip destination and mode choice models will be collected through surveys. The third step will involve the development of models for destination and mode choices. In the last step, the developed model will be validated based on existing data such as *Transearch.*

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The supply chain was studied to demonstrate a typical case illustrating its possible components. Commodities were examined at the four-digit STCC level, and specific case studies were analyzed. A sample supply chain was compiled and information about the time restrictions of the shipments and the production characteristics was determined for different products. By understanding the needs and functions of the supply chains, trip chains were formed, linking raw materials suppliers to the final consumer. Mode choice was shown to be based on the time constraints and shipment reliability required to meet the customer's demands. The findings of this investigation may be summarized as four items:

1. A freight modeling approach was proposed, replacing today's model of freight movement by the public sector with a more accurate model that draws on knowledge of the supply chain and associated logistical decisions from the private sector. The model reflects the four-step urban planning model supplemented with behavioral characteristics associated with freight movements.

2. More detailed data are needed before the trip chains for products can be developed and used to answer specific modal related freight planning questions. Data that supplement the *Transearch* data on modal choice, loading factors, intermodal hubs, and route choice are needed to make accurate decisions regarding improvements to the freight infrastructure.

3. Currently, officials make infrastructure improvements based on what is "broken" in the transportation system. The freight planning process should be proactive and resolve these infrastructure problems before they become obstacles to freight movement.

4. Additional data are also needed to determine ways to convert freight tonnage to vehicles. The load in each vehicle varies dramatically from empty to fully loaded. Assumptions about the degree to which a vehicle is loaded are consequently almost impossible to make. For commodities 3500, 3600, and 3700, the assumptions are complex; this is due to the high dependence on transport mode to keep costs down and the resulting varying modal choice decision.

To advance freight modeling research, future investigators need to replicate the behavior of decision makers in a pull logistics system. This can be done with existing trip attraction equations for industries that do not subcontract production of components and that ship products from the manufacturing plant to retailers. However, new attraction equations are needed for industries that use intermodal facilities (e.g., Ford's mixing plant centers are one example) as well as industries that use distribution centers (e.g., Wal-Mart). Furthermore, in both cases, better mode choice models are needed. Such mode choice models would be based not only on trip length or distance, but also on reliability of travel time (e.g., as a function of variability) to better capture the essence of the JIT requirements.

RECOMMENDATIONS

1. The findings of this research should be used a guide to VDOT's future efforts into freight transportation planning.

2. VDOT's future freight transportation planning studies should consider representative commodity supply chains as the basic level of behavioral analysis for freight transport decisions and use that reference as the basis for more aggregated methods.

3. Models should be established using the framework shown in Figure 3 that interweaves the stages of the supply chain with public sector freight planning.

4. Surveys should be designed and implemented to determine information required to define trip destination and mode choice characteristics of the selected commodity flows. This would reflect the various sub-origins and destinations in the supply chain, and the commodity/vehicle relationship foe the different modes.

5. The local data should be used in conjunction with updated *Transearch* data to calibrate models.

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APPENDIX

State Contacts for Freight Planning

State	Contact Name	Address	Contact Phone Number	Email
Alabama	Jeff Brown, Research and Development	3700 Fairground Rd, Montgomery, AL 36110-2060	334-206-2209	
Arizona	Susie Avelar	Mailbox 310B, PO Box 13588, Phoenix, AZ 85002-3588	602-712-7333	sAvelar@dot.state.az.us
Arkansas*	Cliff McKinney	Arkansas State Highway and Transportation Department, Planning and Research Division, PO Box 2261, Little Rock, AR 72203-2261	501-569-2207, 501-569-2341	Cliff.McKinney@ahtd.state.ar.us
California	Joan Sollenberger	1801 30th St, Sacremento, CA 95816-8041	916-653-0913	
Colorado*	Marilyn Beem, State/Regional Planning	Room 606, Empire Park Bldg, 1325 S. Colorado Blvd., B606, Denver, CO 80222	303-757-9973 or 9795 or 9759	Marilyn.beem@dot.state.co.us
Connecticut	Stuart Leland	2800 Berlin Turnpike, Newington, CT 06131-7546	860-594-2000	Stuart.Leland@po.state.ct.us
Delaware*	Michael Kirkpatrick	Office of Planning, 800 Bay Road, Dover, DE 1993	302-760-2153	mkirkpatrick@mail.dot.de.us
Florida	Rafael De Arazoza	FI Depart of Trans, 602 S. Miami Ave, Miami, FL 33130	305-377-5910	Rafael.DeArazoza@dot.state.fl.us
Georgia*	Marta Rosen	No 2 Capitol Square, SW, Rm 372, Atlanta, GA 30334	404-657-5226	Marta.rosen@dot.state.ga.us
Idaho	Charlie Rountree	PO Box 7129, Boise, ID 83707	208-334-8484	Crountre@itd.state.id.us

State Contacts for Freight Planning (continued)

State	Contact Name	Address	Contact Phone Number	Email
Illinois	Rose Zigenfus	Room 316, 1 NW ML King Blvd, Evansville, IL 47708	812-426-5230	rzigenfus@evansvillegov.org
Indiana*	Barry Partridge	PO Box 2279, 1205 Montgomery St, West Lafayette, IN 47996	317-232-7510 ext 251	Bpartridge@indot.state.in.us
Iowa*	Phil Meraz (Strategic Highway Research Program)	Office of Trans. Data, 800 Lincoln Way, Ames, IA 50010	515-239-1526	Phillip.Meraz@dot.state.ia.us
Kansas*	Jim Tobaden, Bureau of Transportation Planning	915 Harrison, Room 830, Docking, State Office Bldg, Topeka, KS 66612-1568	785-296-3841	jimt@ksdot.org
Kentucky*	Division of Planning, Annette Coffey	125 Holmes St, Frankfort, KY 40622	502-564-7183	Annette.Coffey@mail.state.ky.us
Louisiana	Chester Wilmot, Intermodal Planning	4101 Gourrier Ave, Baton Rouge, LA 70808	225-767-9131	
Maine*	Robert D. Edler, Office of Freight Transportation	16 Statehouse Station, Augusta, ME 04333	207-624-3560	Robert.elder@stte.me.us
Maryland	Dennis N. Simpson, Chief of Regional and Intermodal Planning Division	C502 MDOT State Highway Administration, 707 N. Calvert St, Baltimore, MD 21202	410-545-5675	dsimpson@sha.state.md.us

State Contacts for Freight Planning (continued)

State	Contact Name	Address	Contact Phone Number	Email
Massachusetts	Luisa Paiewonsky	Director of Planning, 10 Park Plaza, Suite 4150, Boston, MA 02116	617-973-7858	Luisa.paiewonsky@state.ma.us
Michigan	Susan Brooke	Dept of Trans., Freight Services and Safety Division, 425 W. Ottawa St, PO Box 30050, Lansing, MI 48909	517-373-6494	brookes@michigan.gov
Minnesota*	Allan J. Vogel, William Gardner	MN DOT Office of Freight, Railroads and Waterways Mail Stop 470 395 John Ireland Blvd St Paul, MN 55155-1899	651-296-1613	Al.vogel@dot.state.mn.us
Mississippi	Martin D. Collier	PO Box 1850 Jackson, MS 39215	601-359-7025	mcollier@mdot.state.ms.us
Missouri	Jan Skoubie	105 West Capitol Ave PO Box 270 Jefferson City MO 65102	573-751-7476	skoubj@mail.modot.state.mo.us
Montana	Dick Turner	PO Box 201001 2710 Prospect Ave Helena, MT 59620-1001	406-444-7289	dturner@state.mt.us
Nebraska*	Art Konkey	NE DOT Planning and Project Development 1500 Highway 2 Lincoln, NE 68509-4759	402-479-4795	
Nevada	Multimodal Planning	Nevada DOT 1263 South Stewart St Carson City Nevada 89712	775-888-7465	
New Hampshire*	Jeff Brillhart	PO Box 483 Concord NH, 03302	603-271-2291	Bureau10@dot.state.nh.us

State Contacts for Freight Planning (continued)

State	Contact Name	Address	Contact Phone Number	Email
New Jersey	William Beetle, Director of Transportation System Planning, J. Lewis	PO Box 600, 1035 Parkway Avenue, Trenton, NJ 08625-0600	609-530-3855	
New Mexico	Ron Montoya, State BPE Coordinator	NM State Highway and Trans. Dept., Trans. Planning Division, PO Box 1149 SB-1, North Santa Fe, NM 87504-1149	505-827-5248	Ronald.Montoya@mnshtd.state.nm.us
New York*	John Rowan	NY State DOT, Freight and Economic Development Department, State Campus Building 7A, Room 300, Albany, NY 12232	518-457-3406	John.rowan@gw.dot.state.ny.us
North Carolina*	Debbie Hutchings	NC DOT, Statewide Planning Branch, 1554 Mail Service Center, Raleigh, NC 27699-1500	919-733-2520	dhutchings@dot.state.nc.us
North Dakota*	D. Rosendahl	Department of Planning and Programming, 608 East Boulevard Avenue, Bismarck, ND 58505-0700	701-328-2513	Drosenda@state.nd.us
Ohio	Mark Byram	Ohio DOT, Department of Planning, 1980 W. Broad St., Second Floor, Columbus, OH 43223	614-466-7825	Mark.byram@dot.state.oh.us
Oklahoma	Roger Saunders	200 NE 21st St, Rm 3A7, Oklahoma City, OK 73105-3204	405-521-2704	rsaunders@odot.org

State Contacts for Freight Planning (continued)

State	Contact Name	Address	Contact Phone Number	Email
Oregon*	Steve Kale	ODOT, Transportation Development Division, Transportation Planning, 555 13th St, ND, Salem, OR 97301-4178	503-986-4130	Steven.r.kale@odot.state.or.us
Pennsylvania*	E. Marshall, Thomas A. Stettler, Lugene A. Bastian, Freight Analyst	PA DOT, Bureau of Rail Freight, Ports, and Waterways, 400 North St, 6th Floor, Harrisburg, PA 17120-0064	717-787-2627, 772-2637, 783-8763	emarsha@dot.state.pa.us
Rhode Island*	William Ankner, PhD, Director of RI DOT	Rm 2102 Capital Hill, Providence, RI 02903	401-222-4203	rshawyer@dot.state.ri.us
South Carolina*	John Gardner	Planning, SC DOT, 955 Park St, PO Box 191, Columbia, SC 29201-0191	803-737-2314	gardneris@dot.state.sc.us
South Dakota*	Jerry Ortbahn	Office of Planning and Programs, SC DOT, 700 E. Broadway Ave, Pierre, SD 57501-2586	605-773-3155	Jerry.ortbahn@state.sd.us
Tennessee*	Ben Smith	Public Transportation, Waterways and Rail Division, 505 Dedrick St, Suite 1800, Nashville, TN 37243	615-741-2781	Ben.smith@state.tn.us
Texas	Jerry Bobo	PO Box 22777, Houston, TX 77227-2777	713-627-3200	jbobo@hgac.cod.tx.us
Utah*	A. Matthew Swapp	UDOT Program Development, Urban Planning Section, 4501 South 2700 West, Box 143600, Salt Lake City, UT 84114-3600	801-965-4829	mswapp@utah.gov

State Contacts for Freight Planning (continued)

State	Contact Name	Address	Contact Phone Number	Email
Vermont	Barry Driscoll	1 National Life Drive, Drawer 33, Montpelier, VT 05633-0001	1-802-828-3441	Barry.driscoll@state.vt.us
Washington*	John Doyle	PO Box 47322, Olympia, WA 98504-7322	1-360-705-7931	doylej@wsdot.wa.gov
West Virginia*	Kenneth Ferguson	WV DOT Division of Planning, Intermodal and Special Projects, Building 5, Room A-110, 1900 Kanawha Blvd, E, Charleston, WV 25305-0430	304-558-3165	kmferguson@dot.state.wv.us
Wisconsin	Al Stanek, Bureau of Planning	4802 Sheboygan Ave, PO Box 7910, Madison, WI 53707-7910	1-608-266-1681	Albert.stanek@dot.state.wi.us
Wyoming*	Pat Collins, Director of Planning	5300 Bishop Blvd, Cheyenne, WY 82009-3340	307-777-4375	wydotweb@dot.state.wy.us

*Indicates responding states.