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Framework for Evaluation of System Impacts of Intermodal Terminals using Commodity Flow Data

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16. Abstract

With the challenges attributable to increasing freight traffic and roadway congestion it is necessary to investigate opportunities for better management of goods movements. Rail-truck intermodal freight transportation can be considered as one such solution for reducing long-haul truck traffic on highways. For the rail-truck intermodal freight transportation to act as an effective transportation alternative, it is necessary to evaluate its impacts on the transportation system. A framework for evaluation of rail-truck intermodal terminal projects with qualitative and quantitative measures has been established using public goals and private stakeholder perspective. With the use of a case study, some of these measures have been evaluated. Recommendations have also made on data collection procedures for making a full scale evaluation. The case study selected for the Project is the proposed freight intermodal terminal at Petersburg, Virginia, conceived by the Norfolk Southern Corporation. This analysis formed a bridge between a region and a corridor based analysis. The key findings of the study are as follows: (a) Evaluation of an intermodal terminal project requires a systematic multi-regional modeling approach; (b) The impacts of an intermodal terminal are region and trade corridor specific; and (c) In cases where estimated intermodal rail drayage forms a small share of the overall truck traffic, the introduction of an intermodal terminal does not have substantial impacts on accessibility, mobility or safety. The study successfully developed models for estimation of impacts, including a two-stage accessibility model for drayage, a truck-rail mode choice model, truck involved crash models, and secondary local freight traffic impact model, mainly using data from the Commonwealth of Virginia.

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ABSTRACT

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CHAPTER 1: INTRODUCTION

1.1 Background

1.1.1 Definition of Intermodalism

According to the Transportation Research Board, in the narrowest usage of the term, intermodal freight transportation refers to transport of goods in containers that can be moved on land by rail or truck and on water by ship or barge [1]. There are variations in definition of intermodal freight transportation available in the literature [2]. Broader definitions also include trailers as intermodal units that use more than one mode for transportation during a single shipment.

1.1.2 Differences between Intermodalism and Traditional Freight Transportation

Intermodalism is considered one of the important advancements in the area of freight transportation and logistics. It is reflective of the structural changes that occurred in the transportation industry over the past two decades [1]. For example, the carriers that were traditionally defined by a mode began redefining themselves in terms of services offered. In addition to the major transportation activity between the terminals closest to the origin and destination of the shipment, other services were offered such as warehousing, drayage trucking, and terminal operations including provision of freight transfer equipment, storage spaces, and labor for loading/unloading, etc. Some or all of these activities are outsourced to external agencies such as Intermodal Marketing Companies (IMCs), or Third Party Logistics (3PLs) [3]. The IMCs or 3PLs in turn purchase rail, truck and other transportation services, utilize equipment from multiple sources, and provide the value-added services under a single freight bill to the ultimate shipper.

From the perspective of a logistics manager, the use of intermodal units instead of traditional freight units leads to higher productivity, faster transit and safer transport due to greater modularity, small handling times and absence of intermediate consolidation and/or deconsolidation steps, respectively [4]. Also, the range of products that can be transported intermodally, say, over rail is far more than the traditional rail system.

1.1.3 Growing Importance of Intermodalism

With significant growth of intermodal freight transportation from late 1970s following the deregulation of all modes, it was realized by public agencies that intermodalism is an emerging area of freight transportation. Taking the example of rail intermodal, the traffic rose from 3.1 million trailers and containers in 1980, to 11.7 million units in 2005. In 2003, rail intermodal surpassed coal for the first time ever in terms of revenue for US Class I railroads, and the revenue contribution stands at 23 percent of intermodal freight for Class I carriers. It is interesting to note that the doubling of the 1980 rail intermodal traffic occurred by 1990 [5]. But, it was only in the past decade and a half that legislature in terms of Transportation Acts (ISTEA[*], TEA-21[#] and SAFETEA-LU[↑]) has been enacted to make the multimodal approach to freight transportation planning a practice at the Federal, State and Metropolitan levels. The aim was to find more economic and efficient ways to transport freight, with intermodalism as a primary consideration towards achieving this goal [6]. Intermodalism gained further attention both in the public and private domains when the globalization of the economy

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[*] ISTEA –Intermodal Surface Transportation Efficiency Act
[#] TEA-21 – Transportation Equity Act for the 21st Century
[↑] SAFETEA-LU – Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users

and increase in international trade started putting pressure on the nation's highway infrastructure [7].

1.1.4 Current Status of Intermodalism

Intermodalism is an evolving area of freight transportation. It is continually being improved to become more competitive. The steps that are being taken up by private stakeholders are: (a) Identification of critical requirements for success of intermodal freight transportation; (b) Use of supply chain management techniques, such as sharing of information and establishing protocols; (c) Improvement in equipment related technology; and (d) Innovations in financing. From public sector perspective, efforts are being made for inclusion of public sector concerns in planning of intermodal freight transportation projects and establishing a freight project selection process.

Some instances of the major improvements that have already been undergone are:

- Shift to more economic and efficient hub-and-spoke systems (in lines similar to airline or less-than-truck-load (LTL) industry) by consolidations, mergers and reduction in redundant trackage;
- Integration of information technology applications in daily operations;
- Outsourcing of transportation and logistics, and in some cases even business models by shippers to external agencies and/or supply chain consultants; and
- Frequent consultations between shippers and carriers, or shippers and IMCs, carriers and IMCs

1.2 Problem Definition

Based on previous studies conducted by the Center for Transportation Studies (CTS) at University of Virginia and review of public documents, it was found that, although there have been several recommendations on the possible role of the public sector in intermodalism, the integration of intermodal freight issues into the transportation planning process for qualitative as well as quantitative analysis and decision making is not complete in most States within US, including the Commonwealth of Virginia. Thus, the number of studies found in literature that incorporated public sector concerns within the framework of intermodal freight transportation planning and operations are very few. According to the Transportation Research Board, there is lack of standard methods for evaluating freight infrastructure investment proposals [1].

This Study focuses on an intermodal rail-truck freight terminal project and the development of a framework for evaluating its qualitative and quantitative impacts on public sector concerns, i.e. mobility, accessibility, economic development, safety, the environment and the community. The key outcomes of the framework are identification and classification of system impacts and development of models for evaluation of these system impacts, where feasible. The use of these results in a project selection process is described.

This research was carried out using a case study with the objective of applying the model and generalizing the findings wherever appropriate. The case study selected was the proposed freight intermodal terminal at Petersburg, Virginia (hereinafter also referred to as the “Study Facility”). The facility has been conceived by a private railroad company, the Norfolk Southern Corporation, to increase their intermodal business near Richmond, Virginia.

1.3 Study Objectives

The Study objectives were as follows:

(a) Compile literature and identify issues related to intermodal freight terminal planning and operations that need to be addressed;

(b) Develop a framework for characterizing the impacts of an intermodal freight terminal project on mobility, accessibility, economic development, safety, the environment and the community;

(c) Apply the impact analysis framework to a case study facility and assess to what extent the terminal addresses the identified freight concerns; and

1.4 Scope

The following are the limitations on the scope assumed for the Project:

(a) Interviews with terminal managers were carried out for terminal locations in the Mid-Atlantic and Southeastern parts of US.

(b) The Study Facility forms part of a Heartland Corridor project (Refer to **2.5.1**), and hence the intermodal traffic to be served by the Project Facility is assumed to be mainly domestic.

(c) The impacts considered in the modeling are not necessarily exhaustive but are reflective of the available resources, and time and budgetary constraints of public agencies in the analysis phase. To the extent possible, efforts have been made to avoid leaving out any important measure of impact.

(d) Full evaluation based on the theoretical framework for the case study was not performed due to time constraints on the Study. However, this Study recommends strategies for additional data collection.

1.5 Structure of the Thesis

This Thesis is divided into several chapters, the descriptions of which are as follows:

Chapter 1 This chapter provides introduction to subject matter of this Study and describes the background for the Study, along with the problem definition and the Study objectives. A brief description of the scope is also presented followed by the structure of the entire thesis.

Chapter 2 This chapter provides the literature review covering areas of rail-truck intermodal freight terminals, mainly its characteristics, and the unique planning and operational issues. Also, findings on these aspects based on interviews with intermodal terminal managers in the Mid-Atlantic region are presented. Following this, some of the existing reports and freight project evaluation techniques are discussed. The remainder of the chapter deals with a description of available data sources.

Chapter 3 This chapter details the methodology followed in the Study. The framework for impact evaluation along with a flowchart, models used and types of evaluation techniques have been described. The assumptions, basis for selection, and nature of inputs and outputs for the models are presented.

Chapter 4 This chapter provides a summary of consultations made with public agencies and a railroad company to obtain information on the case study facility and the case study region. It describes processing steps to generate model inputs and scenarios. The results in the form of model outputs have been used to generate quantitative measurements of impacts and then interpreted. In addition, the qualitative impacts have also been summarized.

Chapter 5 This final chapter presents the conclusions of the Study and discusses the significance of modeling efforts. This chapter also describes the limitations of the Study and provides perspectives on future research.

CHAPTER 2: LITERATURE REVIEW

2.1 Components of the Rail-Truck Intermodal System

The general principle behind rail-truck intermodal freight transportation is that it can yield savings compared with truck alone if the cost of the transfer (the cost of the handling of the intermodal unit plus the cost of the difference in speed and reliability between truck and intermodal) is offset by rail's lower cost per ton-mile. A schematic representation of overall rail-truck intermodal system is indicated in **Figure 1**.

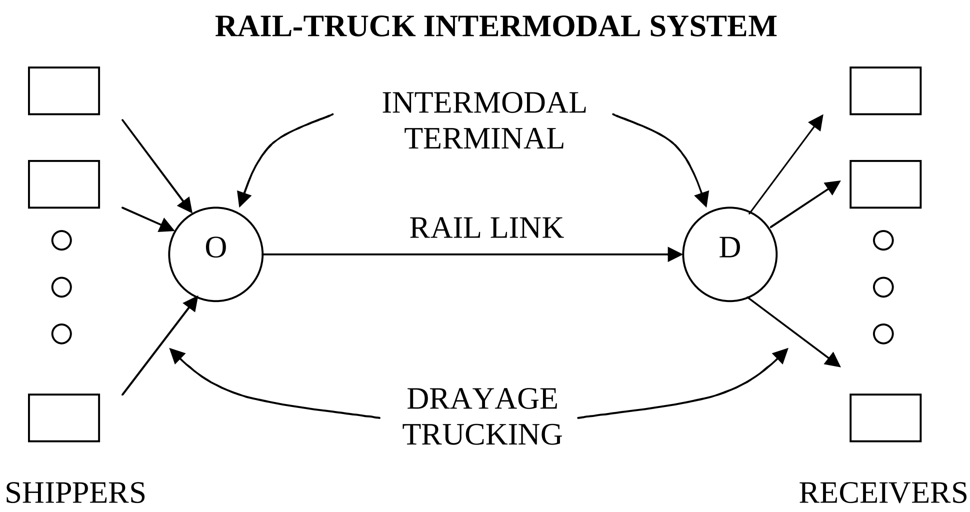

Figure 1. Schematic Diagram of Rail-Truck Intermodal System

The components of the rail-truck intermodal system are identified and described as follows ([3],[4],[8]-[11]):

2.1.1 Rail System

The US rail system is one of the largest with 558 common carrier freight railroads, approximately 177,000 freight employees and more than 140,800 miles (excluding trackage rights) of active track network as on end of 2004. The railroads have been grouped into separate classes based on their operating characteristics as: (a) Class I railroads (See **Figure 2**); (b) Regional railroads; (c) Local linehaul carriers; and (d) Switching and terminal (S&T) carriers

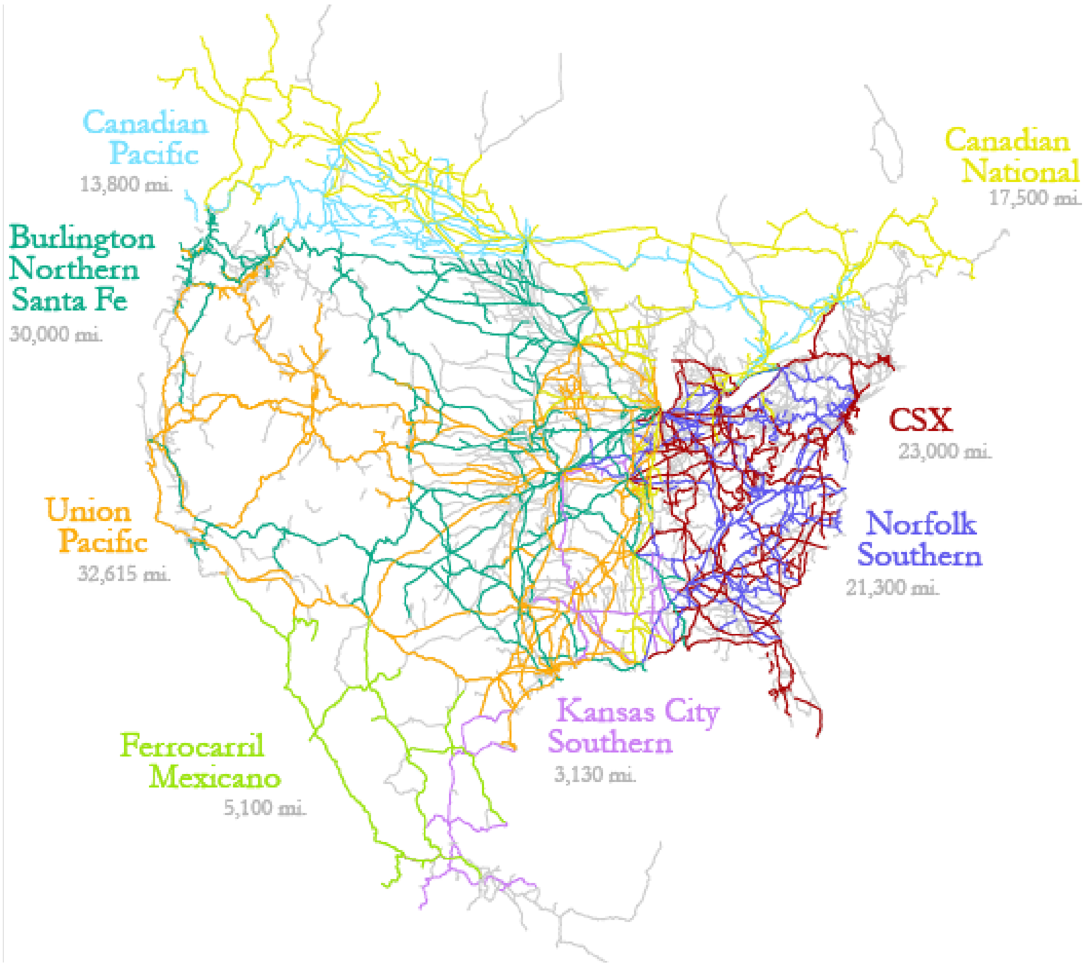

Figure 2. North American Class I Railroad Network*

Well over 90% of US freight railroads, including all Class I carriers and all but one regional railroad, are privately-owned and operated. Major US freight railroads receive little appreciable government funding unlike the passenger railroads, which are heavily subsidized. A vast majority of the trackage is owned by the railroads themselves, who incur large expenses on construction and maintenance of their rights-of-way and pay significant amount in the form of property taxes on their rights-of-way and facilities.

* Source: http://encyclopedia.quickseek.com/images/North_American_Rail.gif

The rail ton-mile share has been trending slightly upward with the growth in rail intermodal over the past 10 to 15 years, after falling steadily for decades. Coal is the most important single commodity carried by rail, accounting for 43% of tonnage and 20% of revenue for Class I railroads. Other major commodities include chemicals, nonmetallic minerals, food and food products, steel and primary metal products, forest products, motor vehicles and motor vehicle parts, and waste and scrap materials.

The services offered by intermodal rail include: (a) Trailers on Flatcar (TOFC); (b) Container on Flatcar (COFC); (c) Doublestack (DS); and (d) Carless Technologies. The majority of intermodal railcars used by the North American rail industry is owned and managed by TTX Company, i.e. almost 91% of the Class I railroad mileage. Over the past ten years, TTX has invested 3.9 billion in new railcar purchases (with 61% for intermodal cars).

2.1.2 Drayage

Drayage is the movement of a container or trailer by highway carrier between the intermodal freight terminal and point of origin or destination of shipment. Typically drayage is undertaken for distances of less than 100 miles, although there are some instances where drayage might be undertaken for much larger distances. Drayage is carried out based on contract(s) between the drayage trucking firm(s) and either the agency for intermodal terminal operations or the shippers. The driver of the trucking firm will provide the actual interface with the shipper for pickup or receiver for delivery. The driver may perform either adopt a “drop and pick” or “stay with” policy while loading/unloading of trailer is carried out by shipper/receiver.

Drayage forms a significant portion of the cost of transportation, and can be as high as 40% of the cost of an intermodal move. In cases of short haul freight movements or when the shippers are located at large distances form the terminal drayage costs can dominate. It is interesting to note that although most of the drayage agency costs are time-based, e.g. labor and equipment; the service is often priced by the move rather than by the hour.

2.1.3 Intermodal Terminal Facility

Intermodal freight terminals (See **Figure 3**) form an interface between the highway and rail modes. They are locations where the modal transfer of freight occurs.

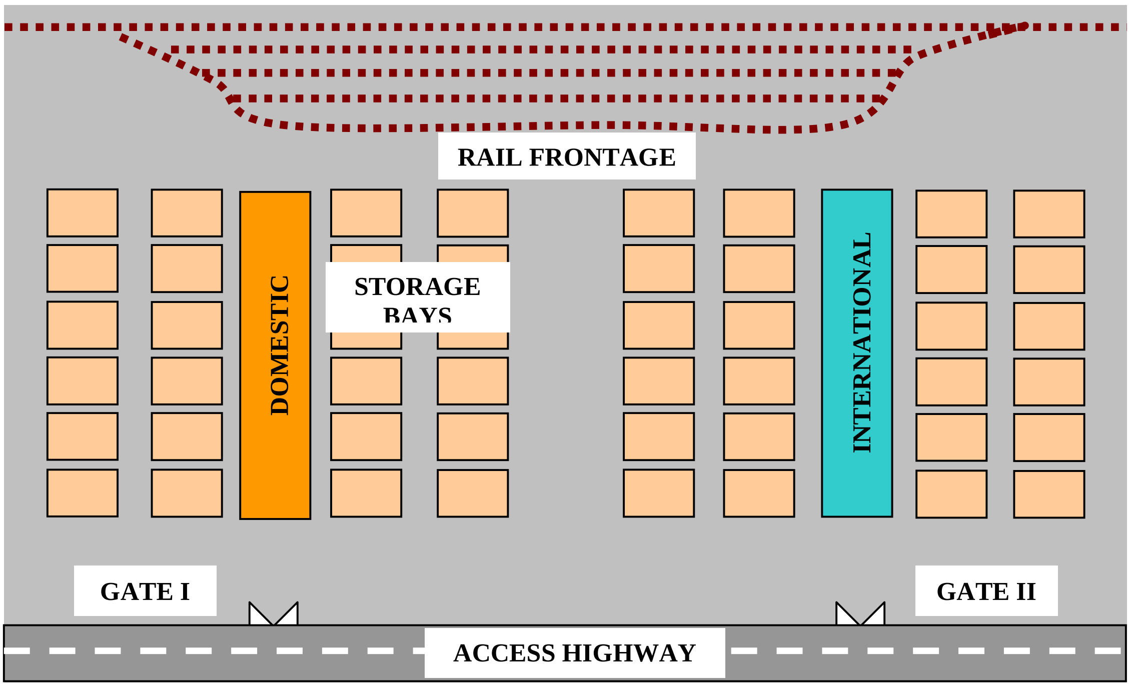

Figure 3. Typical Layout of Rail-Truck Intermodal Freight Terminal

During the early years of TOFC service, due to low volumes the railroads used a technique called circus loading to handle intermodal transfer. This loading employs ramps, either portable or fixed, placed at the end of the railcar. Using the tractor, trailers are moved up the ramp and onto the railcars. This operation has several disadvantages. A trailer cannot be unloaded without either moving all trailers between it and the ramp or reorienting the railcars by switching, thereby resulting in low productivity levels for loading and unloading. However, this process is inexpensive to build and operate, especially for low volume locations.

In the past few decades, mechanization of intermodal terminals to perform lift based loading and unloading operations has significantly improved productivity. The lift equipment can move containers or trailers without a chassis and have contributed greatly to the efficiency of trailer and container movements.

The categories of equipment that are in common use nowadays are sideloaders, forklifts, reachstackers, straddle loaders, and gantry cranes. Sideloaders are relatively low cost machines especially well suited to trailer handling. Gantry cranes are high-end machines suited to high volume container and trailer loading. The increase in productivity has a high investment profile with sideloaders and gantries costing anywhere from a half of a million to several million dollars. In addition, mechanization needs the terminal to be designed and constructed for equipment operations, such as sufficient spacing between tracks for loading and unloading processes and design of pavement to withstand equipment wheel loads. This further adds capital investment requirements for the terminal. Also, skilled labor with sufficient training is required for using this equipment.

In a few specialized intermodal terminals, loading and unloading processes are handled through non-lift based technologies, e.g. network of terminals using Triple Crown’s RoadRailer carless technology. Developing doublestacking capabilities at selected intermodal terminals may also impose changes in equipment specifications.

Due to the need for high capital investments and the scale economies of mechanized lift and non-lift based equipment and technologies, intermodal terminals have undergone consolidation to form a hub-and-spoke system. In such a system, linehaul movements are comparable to movements between hubs, and over the road movements are comparable to spokes.

2.2 Characteristics of Rail-Truck Intermodal Freight Terminal

According to McCalla et al [12], some of the evident and common characteristics of freight transport terminals are:

(1) they enable the transfer of freight from one mode to another;

(2) they require extensive land;

(3) they require a high degree of accessibility to roadway system;

(4) they have a relatively low rent-paying ability; and

(5) they generate certain environmental externalities particularly associated with noise and traffic congestion

To develop a systematic impact evaluation framework, literature review was performed to further understand the input and output characteristics of a rail-truck intermodal freight terminal (See **Figure 4**, hereinafter referred to as the “intermodal terminal” or the “terminal”) and the associated planning and operational issues as follows:

2.2.1 Demand

Demand at an intermodal terminal is the outcome of commodity flows occurring from/to the region where it is located and is rarely intra-regional by nature. The rail inclusive intermodal industry faces stiff competition from other modes of transportation, especially the trucking industry (Refer to **1.1.4**).

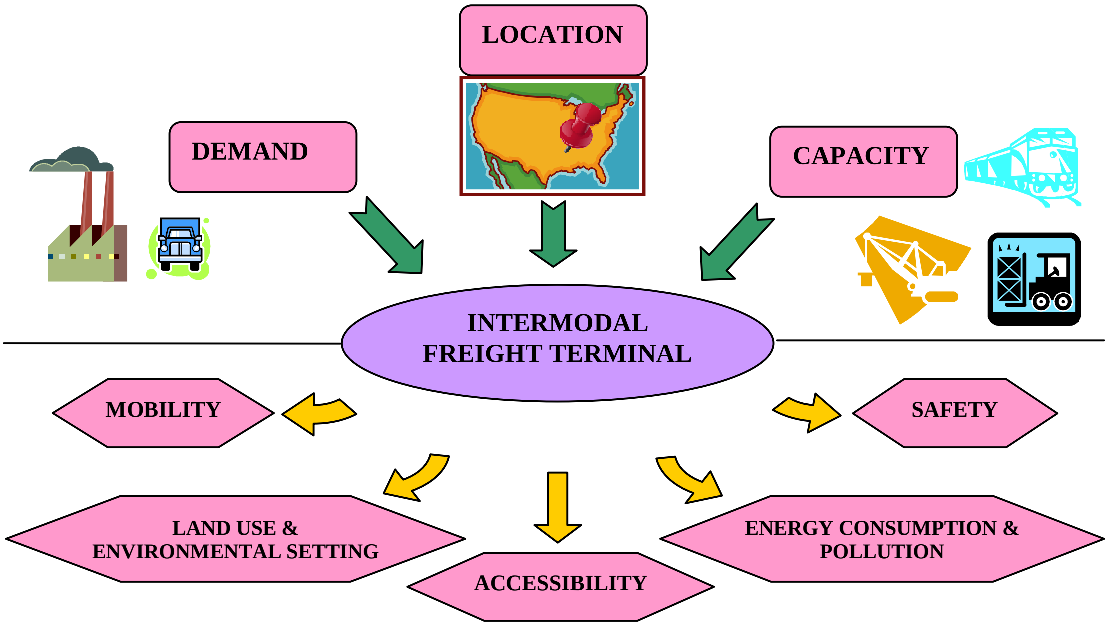

Figure 4. Input and Output Characteristics of Intermodal Freight Terminal

Cullinane and Toy [13] used content analysis on existing body of freight literature to systematically identify most influential attributes in freight mode/route choice analysis. The top five attributes identified are as follows: (a) cost/price/rate; (b) speed; (c) transit time reliability; (d) characteristics of goods; and (e) service. According to the authors, the service characteristic is the most difficult to quantify. Some of the other attributes identified in literature are frequency, distance, flexibility, infrastructure availability and accessibility, capability in terms of service and equipment, loss/damage, control and tracking, and previous experience of shippers.

Another challenging problem is the balance of trade that an intermodal business can achieve. Agents of the railway as well as those of the shippers (such as IMCs, 3PLs, Refer to **1.1.2**) can most effectively reduce the gap of loaded inflows to and outflows from a terminal. Mr. Eric Potter, Tropicana Products Inc. in his presentation at the 86th

Annual Meeting of Transportation Research Board stated that backhaul arrangements to cut down empty flows need geographical fit, agreement to rates, compatibility of freight streams in both directions, supply chain and operations coordination of both customers, and finally sorting of accounting issues. The remaining empty hauls, be it rail cars or drayage units, need good management. Operations research is presently the best way to address this issue [14].

2.2.2 Location

A number of factors influence intermodal terminal location decisions. McCalla et al [12] based on their survey found that spatial proximity of industrial firms to an intermodal terminal alone is not sufficient for great usage of that transportation facility, as in some cases this situation can be incidental. Other factors include proximity to market (customers, distributors and suppliers); space requirements; access to transportation infrastructure (other than the intermodal terminal, for e.g. truck routes, railway lines, port etc.); industrial growth in selected area; rental costs and types of intermodal freight; container and vehicle characteristics and accessibility to labor.

Terminal location can be a result of interests/disinterests shown by various land use groups (commercial, residential, etc.), which like in any other location problem of transportation project deals with issues on local community impacts, their distributive effects, and external forces [15]. Also, the provision of transport improvements in the environs of the terminal may have indirect effect of facilitating intra-regional movements.

2.2.3 Capacity

From an investment and planning perspective, capacity needs to match the demand, throughput and service requirements, and thus relates to the size of facility, land available for expansion, number and capacity of tracks, size and type of equipment, crew size and their skill levels, capacity on road connectors to the terminal, and other support infrastructure such as storage and office buildings, communication and ITS technologies, etc. Flexibility in handling various sizes of containers/trailers, and providing various levels of service are also key elements to attract intermodal business.

Operational capacity of intermodal terminals can be measured in terms of the gate capacity, the track capacity, the loading/unloading cycle length, and the parking capacity [16]. Some of the related issues are equipment utilization, productivity of crew, train schedule performance, traffic management, empty car distribution, and parking requirements. Long throughput times affect the stationary time and non-productive time of trains at the terminal and may cause congestion at the terminal [17].

2.2.4 Mobility

Intermodal freight transportation is not a complete solution to the problem of congestion on trade corridors and metropolitan areas in the US. As expressed by Mr. John Gibson, CSX Transportation Inc. in his presentation at the 86th Annual Meeting of Transportation Research Board, increase in rail based freight transport cannot necessarily eliminate congestion on highways. Some of the reasons stated were: (a) excessive levels of current and future demand for both freight and passenger transportation, beyond capacity of all forms of available transportation infrastructure; and (b) slow rates of highway and rail investment due to lack of funds, non-profitability, lack of space, and environmental concerns.

The investment in new rail-truck intermodal infrastructure helps in merely reducing certain undesirable long drayage movements for existing intermodal traffic and diverting part of long-haul truck based freight movements to rail. Intermodal terminals also generate hitherto absent local truck drayage movements. The impact of such movements on local mobility can only be assessed based on the location decision made at project level. Assuming no capacity constraints and congestion on long-haul rail, it can be said that the intermodal terminal transforms the mobility problem of several lines/corridors form to twin points/regional form.

Relatively, a more manageable problem on mobility is that of the minimization of throughput times at the intermodal terminal with a given set of resources. This has been extensively studied using the techniques of operations research [18].

2.2.5 Accessibility

Intermodal terminals are neither the true origin nor the true destination of freight flows. Hence, they require high degree of accessibility to other transportation infrastructure. According to NCHRP Report 466, the structure and capacity of the transportation network affect the level of accessibility within a given area [19]. In the case of the intermodal terminals, this can be directly related to the geometric characteristics, pavement condition, capacity, and height and weight restrictions on connecting road network. Terminal projects should ideally be combined with sufficient roadway capacity addition and/or geometric improvements on adjacent road network to minimize the pickup/delivery times and the negative impacts that drayage movements from/to the terminals can have on areawide accessibility.

The other aspect of accessibility is that of accessibility of the terminal to skilled labor. The categories of labor activities include equipment operation for loading/unloading, sorting and stacking; document verification and equipment identification at gates and tracks; track operations and rail car management; drayage operations and truck fleet management. The availability and accessibility of labor with relevant experience and/or training in the vicinity of the terminal at affordable wage rates is critical to the intermodal terminal owner/operator in achieving required throughput.

2.2.6 Land Use and Environmental Setting

According to NCHRP Report 456, changes in property values are a product of changes in accessibility and various social and economic effects (community cohesion, economic development, traffic noise, and visual quality) [15]. A transportation project bringing about any of these effects is likely to influence property values and the use to which the land is put. More expensive land will tend to be used intensively. However, projects that increase accessibility of undeveloped areas will tend to promote lower-density land use patterns due to the availability of relatively inexpensive land.

Barton et al [20] in their study undertaken in Minnesota found that the location of intermodal terminals often has depended on where railroads had spare land adjacent to freight rail lines. Many of these locations were less than ideal in terms of surrounding land uses and offered little scope for expansion as intermodal traffic grows. This means that in reality most of the terminals are Brownfield projects, and are providing accessibility to rail more often to developed areas than undeveloped areas.

Morlok and Spasovic [21] suggested that as the location of the terminal exerts a great influence on the efficiency and cost of drayage, land use policies that concentrate industry and other cargo traffic generators in locations that favor the use of intermodal will enhance its potential. Examples for such policies are co-location of establishments, new developments in the vicinity of the terminal, and picking location alternative that minimizes use of high traffic roadways.

2.2.7 Safety

Chatterjee and Stamatiadis [11] suggested that intermodalism has an impact on highway safety by shifting traffic away from the highway mode to rail over some portion of a distribution channel. They attempted to quantify the changes in the truck travel patterns and the resulting in truck vehicle miles traveled (VMT).

Lyles et al [22] developed statistical information on the risk of crash involvement for Michigan-registered trucks in Michigan. This helps understand the affects of reduction in truck VMT on highway safety. Their study disaggregated truck crash rates by road class, day or night, and urban or rural operating conditions for different vehicle configurations. The most significant and consistent factor associated with truck crash rates was found to be the roadway class (highest rates on the “local” road system, lowest on limited-access highways). Urban crash rates were lower than rural crash rates. Finally, they also found that the type of access roads and vehicle category used for drayage movements can have significant impacts on highway safety.

Harwood and Glauz [23] present the state of knowledge and the state of the practice concerning the accommodation of heavy vehicles on the highway. They discuss the influence of physical and performance characteristics of a wide variety of heavy vehicle types, highway geometric design features, traffic control devices and traffic regulations.

2.2.8 Energy Consumption and Pollution

Similar to safety impacts, reduction in truck VMT and use of rail for long-haul result in energy savings and pollution cost reductions. However, it is reminded that energy is also consumed in material handling activities at the intermodal terminal.

The energy consumption for freight transportation as of 2004 taking truck, Class I Railroad and water modes taken together is about 6400 trillion BTUs (i.e. 6.75 EJ* (ExaJoule)) [24]. Transportation related national aggregates of energy consumption by mode and greenhouse gas emissions are available in the Transportation Energy Data Book of US Department of Energy [25].

Vanek and Morlok [26] based on their 1994 statistics noted that energy consumption in freight transportation is roughly one-third of the energy consumption of passenger transportation and about 7-9% of total end-use of energy in the United States; and it would continue to rise for trucks at a rate much higher than other modes of transportation, along with rise in concomitant fuel emissions.

According to US Environmental Protection Agency (EPA), for long distances (over 1,000 miles) intermodal freight transport can cut fuel use and greenhouse gas emissions by 65 percent, compared to truck-only moves [27]. Based on the Vehicle Inventory and Use Survey (VIUS), it is evident that energy intensity of vehicles (measured in BTUs/ton-mile) has been declining over the years by increasing use of idle reduction technologies (for e.g. microprocessor controlled Engine Control Unit (ECU)), navigational system to minimize stop-and-go traffic, radial tires, air springs for suspension, and other equipment and technologies [28]. It is helpful to consider such

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* $1 \text{EJ} = 1 \text{x} 10^{18} \text{ J} \approx 9.4845 \text{ x} 10^{14} \text{ BTU}$

factors and the indirect energy uses (non-transportation related) in more accurate estimation of energy impacts of reduction in truck VMT and/or shift to rail mode.

2.3 Interviews with Intermodal Terminal Managers

In order to supplement findings from the literature review and to get a private stakeholder perspective on planning and operational practices of rail-truck intermodal terminals, a series of phone-based interviews were conducted with the managers of intermodal terminals located in Mid-Atlantic region (See **Appendix A** for a sample questionnaire). The selected terminals are indicated in **Table 1**.

The focus of these interviews was to learn about different aspects of the intermodal terminals, such as history of the terminal, current operations, coordination efforts with public and other private stakeholders, and future of intermodal terminals. Useful information was collected regarding the role of public and private sectors in establishing the terminal, extent of market coverage, services provided, commodities handled, possible sources of funding, opportunities for shipper feedback, public support needed, management practices and techniques used to improve coordination between the work units, critical factors that influence a shipper's decision, and lastly, factors that contribute or deter the success of intermodal terminals.

Table 1. Selected Intermodal Terminals for Interviews

Sl No	Railroad Owning Intermodal Terminal	Location
1	Norfolk Southern	Charlotte, NC
2	CSX	Nashville, TN
3	CSX	Charleston, SC
4	CSX	Cincinnati, OH
5	CSX	Syracuse, NY
6	BNSF*	Memphis, TN and Birmingham, AL

* Interview was conducted with Vice President - Intermodal Operations, BNSF

Excepting the questions 1(a), 1(b), 3(a) and 3(b) of the questionnaire attached in Appendix A, pertaining to the rail-truck terminal funding, development and the marketing of intermodal service, almost all interviewees provided precise responses. Overall the interview results have been satisfactory.

Some of the key observations and generalizations that can be made based on the interviews with terminal managers of the selected terminals are as follows:

(1) Intermodal terminals that were constructed more than a decade ago were mainly funded through private capital.

(2) Operations of intermodal terminals have always been funded through private capital. On some occasions the lift and maintenance services at the terminal are contracted out by the railroad companies. In some CSX terminals, drayage service is provided by CSX Corporation itself enabling them to better coordinate such activities.

(3) Intermodal terminals are more likely to be located in a region having extensive road infrastructure (especially interstates) and/or freight generators.

(4) In most cases, the development of warehouse facilities and distribution centers by shippers is a consequence of locating an intermodal terminal in a region; rather than a cause for development of an intermodal terminal. Exceptions to this can occur when one or more manufacturing facilities with high intermodal demand establish ancillary facilities like warehouses and distribution centers close to a rail line.

(5) The split between international and domestic trade, as well as inbound and outbound traffic vary widely for different terminal locations. It mainly depends on

the trade corridor to which it belongs and the regional characteristics, i.e. production and consumption.

(6) It was observed that a practical limit for intermodal drayage can be considered as just over 200 miles. On the one hand presence of other intermodal terminals can reduce this limit, on the other hand lack of transportation alternatives can increase the drayage distances.

(7) Freight carried in TOFC/COFC is mainly categorized as FAK (Freight All Kinds), as a wide range of consumer products are combined in a single shipment. In addition, auto parts, paper, wood and printed matter are other major products transported over intermodal rail.

(8) The marketing and sales divisions of railroad companies directly acquire feedback from the shippers. Additionally, one of the CSX terminals indicated that they are responsive to shipper needs by sending out information on the state of the facility on a day-to-day basis to intermodal marketing companies (IMCs), such as number of available trucks, chassis and equipment.

(9) For the terminals considered in **Table 1**, the railroad companies do not seem to require much support from the public sector, other than in making minor road improvements for maintaining good access to terminal and showing flexibility and cooperation in approving site drainage plans and permitting improvements.

(10) Some of the techniques identified by the terminal managers for improving the efficiency of intermodal transportation are to meet the train schedules and deadlines; use of good communication and data technology (for example,

Radio/Frequency technology), cameras and other forms of automation; use of shorter trains with doublestacking; and reducing terminal dwell times.

(11) Good management practices that are being followed by the terminal managers include daily communications, both verbal and electronic; weekly meetings; monthly reports to the corporate office; cross functional meetings, safety meetings, and “air-out” meetings; and local meetings with trucker/drayage companies related to safety and throughput processes, as well as reaffirmation of processes with beneficial customers/shippers.

(12) According to the terminal managers, critical factors that influence a shipper’s decision to use intermodal service include weight of the commodity, fuel prices, transit times, cost, consistency in service (i.e. reliability), and ease of service. Overall, intermodal rail should be competitive with truck pricing and service.

(13) Looking at critical factors that contribute to the success of intermodal terminals, these include good marketing (regarding price and service); good communications with the trucking community and railroad personnel; support from Local and State municipalities; access improvements; safe, skilled, and knowledgeable personnel; efficient operating practices that encourage expedient removal of units from the facility to allow additional units handled with the same infrastructure.

(14) Some of the deterring factors to the success of intermodal terminals have been identified as space constraints and land-locking due to developments around the terminal; difficulties in achieving trade balance; Environmental Protection Agency (EPA) requirements; shippers/customers who allow long dwell time at the property, or keep chassis supporting the facility operations for extensive periods,

thus creating chassis shortages; and other factors that are opposite to the success leading ones. One of the terminal managers suggested use of satellite lots as a potential solution for space shortages.

(15) Some of the advanced technology applications used by CSX include Radio Frequency (R/F) Technology, ShipCSX[↑], Electronic Data Interchange (EDI) Solutions, and Pegasus. Speaking of Pegasus for example, it is a modern, flexible Transportation Management System used by CSX's trucking group. It is a single, comprehensive, integrated solution for processing orders, performing dispatch functions, managing equipment and drivers, providing wireless connectivity, managing critical document images and providing back-office financial information for various types of intermodal traffic. Employing wireless communications built on BlackBerry technology, drivers can instantly communicate with call centers, and send/receive shipment data from any location at any time.

(16) The interview revealed that train schedules for CSX are prepared centrally at Jacksonville, FL and local decisions are made only on how to reach full capacity of train. According to the terminal manager, intermodal terminals are not just about capacity building but looking at commodities types that can be handled and their requirements. Also, capacity improvements can be made by reducing dwell time and/or increasing hours of operation.

[↑] CSX's e-business (online) tool to plan, ship, trace and pay for shipments

2.4 Measures of Effectiveness (MOEs) and Performance Measures (PMs)

The decision making within railroads, who are the chief owners and/or operators of intermodal business in US is made at strategic (long-term), tactical (medium-term), and operational levels (short-term) [18]. This Study looks at impacts of some of these long- and medium-term decisions on the intermodal terminal characteristics. To assess and to compare these impacts and their effectiveness in addressing the planning and operational issues, measures of effectiveness (MOEs) and corresponding performance measures (PMs) need to be established. In this Study, MOEs are defined as descriptors of the impacts categorized under a specific public sector objective, which in turn falls under a specific public sector goal. MOEs are measured using two components, namely the qualitative and the quantitative. PMs represent the quantitative measurements.

USDOT's report [29] on the use of PMs by the State DOTs shows the state of the practice. As an example, PMs used by the State of New Jersey have been summarized in **Table 2**. It can be seen that the objectives are typically the desired characteristics of the terminal. Here, they substitute the use of MOEs due to their specific application to intermodal freight planning. Also, it can be seen that a single PM definition can simultaneously represent impacts on several working characteristics of the terminal. For example, truck turnaround time affects the mobility as well as the accessibility.

Table 2. PMs used in the State of New Jersey for Intermodal Freight Planning

Objective	Performance Measures
Accessibility	Truck turnaround time Drayage Distance Average drayage time/delays (minutes) Average drayage costs ($ per lift) Customs delays (hrs per shipment) Vertical clearance bridges viaducts and overpasses
Availability	Type of modes handled Loft capacity (annual volume)

Objective	Performance Measures
	Track capacity (size, acreage) Gate facilities (queuing length, wait time) Equipment availability Container storage capacity
Cost and Economic Efficiency	Cost per ton-mile by mode Revenue per ton-mile by mode Operating ratio
Safety and Security	Accident rate Allowable size of trailer
Connectivity between modes or intermodal connectivity ease of connection	Interference of movement at grade crossings-delay time and speed
Time	Average travel time from facility to major highway network (on connector link) Average travel time from facility to rail (on connector link)
Reliability	Roadway and modal level of service
Operational Standards and Productivity	Line haul speed Percentage on-time performance Availability of real-time cargo information Doublestack capacity Primary intermodal service schedule adherence Secondary services status report
Environmental Protection	Air quality/congestion reduction Expansion capability Fuel usage Constraints to utilization due to noise (hours of operation) Constraints to utilization due to water quality (dredge fill permits) Restrictions on hazardous waste transport
Legal and regulatory issues	Weight Restricted Areas Hours of operation
Economic Development	Market share of international or regional trade by mode Direct and indirect jobs created Percent of State gross product

The PMs were originally developed in various States in response to requirements of ISTEA, 1991 (Refer to **1.1.3**), which emphasized use of performance-based planning tools to assess the level and impact of intermodalism. They formed an important part of the Intermodal Management System (IMS), one of the six management systems that were required to be developed by the States [30]. Due to relaxation from these mandates under

Section 205 of National Highway System Designation Act, 1995, the structure of freight planning has taken different shapes in different States.

According to Chairman Mr. Neil J Pedersen of the Transportation Research Board Committee on Statewide Multimodal Transportation Planning, some of the planning activities taken up by the States include customer-based planning and forming partnerships with a diverse public; balancing long-term and immediate needs; investigating alternative financing; solving problems without modal biases; understanding the economic effects of goods movement; adopting new technologies; considering the environment and environmental justice; consensus building; travel forecasting; reengineering the planning process; and recruiting and training qualified professional staff [31]. As a consequence, it was realized that the definitions of MOEs and PMs in this Study are to be made comprehensive enough to reflect the wide range of developments.

2.5 Review of Earlier Reports and Studies

As a natural follow-up task, appropriate public documents were reviewed to identify the planning activities taken up by the State, MPO, and Local Government for the region where the Study Facility is proposed to be located.

2.5.1 VTRANS 2025 and Virginia Port Authority (VPA) Strategic Plan

VTrans 2025 is the Statewide multimodal long-range transportation plan of Virginia developed in three-phase report [32]. It involved coordination among the Department of Aviation (DOAV), the Department of Rail and Public Transportation (VDRPT), the Port Authority (VPA), and the Department of Transportation (VDOT).

Stakeholder outreach was a key component of the Statewide transportation planning process. The list of various goals and objectives identified in this planning document is shown in **Table 3**:

Table 3. Transportation Goals and Objectives listed in VTrans2025

Goal	Objective
Safety and Security	Improve safety for system users and operators within the system and at mode origins/destinations Increase the security of the transportation system and its users Provide infrastructure, facilities, and communications to meet strategic and emergency transportation needs
Preservation and Management	Preserve transportation infrastructure to achieve the lowest lifecycle costs and prevent failure Encourage access management techniques that preserve the operational integrity of existing infrastructure while ensuring appropriate access to adjacent land uses Maximize system utilization by increasing the efficiency of existing facilities and services through use of technology and demand management techniques Maintain the effective and predictable operation of the transportation system to meet shipper's expectations by using technology and demand management techniques Reduce transfer time between modes
Mobility, Accessibility, and Connectivity	Reduce congestion for all modes Ensure seamless connections between modes by providing networks of facilities that facilitate the journey from origin to destination and all connections between Increase capacity for the movement of people and goods Improve access to major activity centers Meet basic transportation needs for special needs populations Expand modal choices

Goal	Objective
Economic Vitality	Improve accessibility of the workforce to employment opportunities
	Improve accessibility of goods to markets
	Improve accessibility of people to goods and services
	Promote efficient use of current and future transportation facilities and services by coordinating transportation planning and implementation with local land use planning and economic development goals
Quality of Life and Environmental Stewardship	Maintain and improve air quality by meeting applicable air quality standards
	Maintain and improve water quality by meeting applicable water quality standards
	Maintain habitat and watershed quality and connectivity
	Preserve Virginia’s rich cultural and historic resources
	Ensure that transportation facilities and services are compatible with the communities and destinations they serve
Fiscal Responsibility	Maximize use of non-State funds
	Maximize the system benefit of investments
	Minimize life-cycle cost
	Leverage opportunities between modes
	Coordinate completion/implementation schedules and funding of interdependent multimodal projects

VTrans2025 identifies barriers to intermodal connectivity in Virginia as physical and institutional. Physical barriers in connection with intermodal freight include poor access to general aviation airports and insufficient clearance for doublestacked trains. Institutional barriers include the traditional “stovepipe” independent modal agency planning currently in place, lack of flexibility in funding programs, policies that discourage intermodal projects, and organizational structures.

Data collection and analysis of transportation-related economic and demographic trends were performed to determine strategic implications to be considered in transportation policies. Transportation strategies suggested in VTrans2025 to address freight were identified as: (a) Increase investment in the State's freight movement infrastructure, including maritime and inland ports, rail, highways, and aviation facilities; (b) Facilitate coordination between private and public interests on freight issues; (c) Consider establishment of a Freight Council made up of stakeholders and others in the industry; and (d) Establish a Freight Office to increase attention to freight movement.

The framework for planning and prioritizing multimodal projects at the State level has been proposed through use of Multimodal Investment Networks (MINs) (See **Figure 5**).

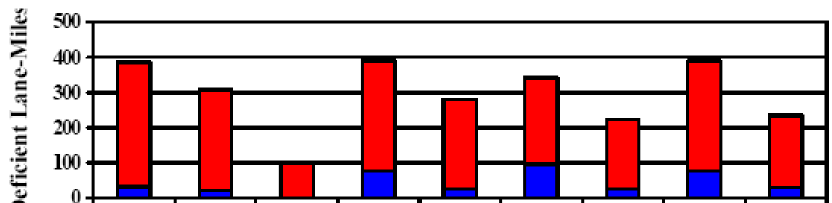
A. Hampton Roads Multimodal Access MIN
B. Richmond to Hampton Roads Passenger and Goods Movement MIN
C. Interstate 95 Passenger and Goods Movement MIN
D. Interstate 81 Passenger and Goods Movement MIN
E. Interstate 73 Corridor/ Franklin County Airport Access MIN
F. Coalfields Access MIN
G. Route 29 MIN
H. Northern Virginia Connections MIN
I. Port Accessibility and Mobility MIN
J. Virginia Bicycle and Pedestrian System MIN
K. Emergency Transportation MIN

(Source: Reference [32])

Figure 5. Multimodal Investment Networks (MINs) Identified in VTrans2025

Multimodal network has been defined as interdependent multimodal projects that collectively serve a common purpose for transportation in the Commonwealth. VTrans2025 also provides criteria corresponding to the set objectives for multimodal prioritization, however, limiting their applicability to multimodal networks.

The Study Facility would have direct influence on the Richmond to Hampton Roads Passenger and Goods Movement MIN. VTrans2025 indicated Richmond construction district has the highest deficient lane-miles of about 391 (See **Figure 6)**. In terms of both Primary and Interstate highway infrastructure, the number of deficient lane-miles is relatively significant for the Richmond district. With port access improvements as per 2040 Master Plan of Virginia Ports Authority, shortages in transportation infrastructure in Hampton Roads region are being addressed to. However, similar solutions need to be provided for the Richmond district.



	1	2	3	4	5	6	7	8	9
Primary	355	286	102	314	256	246	199	313	204
IS	31	21	0	77	25	97	24	76	30

(1) Bristol, (2) Salem, (3) Lynchburg, (4) Richmond, (5) Hampton Roads, (6) Fredericksburg, (7) Culpeper, (8) Staunton, and (9) Northern Virginia

(Source: Reference [32])

Figure 6. Deficient Lane-Miles Based on Route Type and Construction District

The planning documents provided specific description of some related projects:

(1) As per the VPA Strategic Plan, the Heartland Corridor initiative proposes the expansion of a major rail freight corridor stretching from Norfolk to Chicago [33]. It will increase the 28 tunnels and bridges vertical clearances above the high-speed, high capacity Norfolk Southern main line between Columbus, Ohio and

Roanoke, Virginia saving 230 miles and one and a half days. Upon completion, the rail network will have a fully cleared direct route between Chicago, Illinois and The Port of Virginia and all markets in between. This cleared network will provide for the intermodal movement of goods between Virginia, North Carolina, West Virginia and Ohio and the rest of the Midwest in a highly efficient doublestack configuration. This project also provides for a new intermodal facility in the Roanoke Valley region of western Virginia, Pritchard, West Virginia and Columbus, Ohio providing intermodal access to global markets through The Port of Virginia. Over 20 years, the project will provide up to $368 million in economic benefits to shippers moving freight in the Heartland Corridor. The project was one of 13 transportation projects noted in the recently approved SAFETEA-LU transportation bill as a project of national significance.

(2) Work is currently underway to widen a section of Interstate 64 between Newport News and the Hampton Roads Bridge Tunnel in Hampton Roads. Future projects may include additional lanes to the west between Newport News and Richmond.

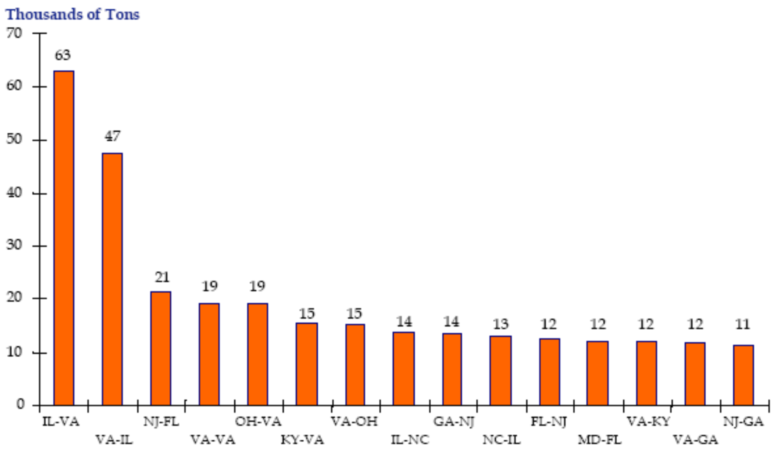
(3) Originally part of the national “TransAmerica Corridor” designated by Federal transportation legislation in 1991, the Route 460 Corridor location study is currently underway to identify and evaluate potential improvements to Route 460 between Hampton Roads and Richmond.

According to VTrans2025, freight rail is funded by two State sources for capital improvements and two Federal sources. The State sources include the Rail Preservation Program and Industrial Access Program of $5.0 million to $6.0 million annually. Federal funds sometimes are available to projects in high-speed corridors of Virginia from the

Railway-Highway Crossing Hazard Elimination Program, and from the Section 130 Railway Highway Crossings Program. Funding to support specific railroad improvements related to highway projects is provided on occasion from highway funding programs such as the Federal Surface Transportation Program (STP) and the State Bridge Fund. Overall, it is found that there is no State funding source sufficient enough to support freight rail. A separate rail fund can help consider rail in the mix of solutions for the transportation capacity problems and promote partnership with the private sector, by using State funds to leverage private sector investment.

2.5.2 Virginia State Rail Plan

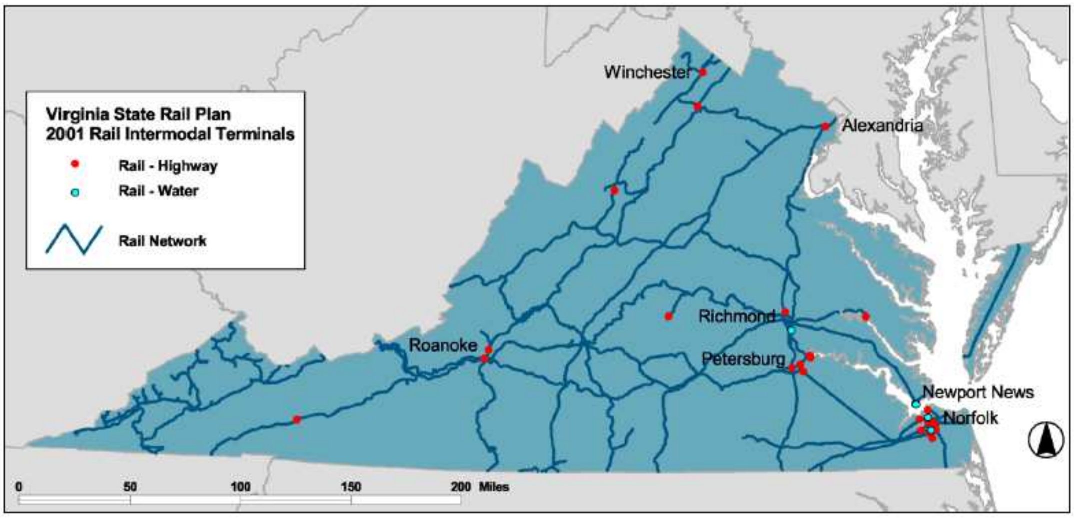
This document provides detailed information on the future needs of Virginia's rail system and introduces strategic recommendations to meet those needs through 2025 [34]. It includes several facts already discussed in review of VTrans2025 under freight rail. Among the other information provided on rail freight movements in Virginia, the intermodal rail shipment tonnages by geography of movements has been presented in **Figure 7**.



(Source: Reference [34], 2001 Surface Transportation Board Carload Waybill Sample)

Figure 7. Intermodal Rail Shipments by Geography

It is observed that most of the intermodal rail traffic in Virginia is east-west oriented, with moves between Illinois and Virginia, Ohio and Virginia, and Kentucky and Virginia predominating. To a lesser extent, north-south moves between New Jersey and Florida, and Georgia and New Jersey are also present. This planning document also provides details on locations of existing rail-truck intermodal terminals (See **Figure 8**) and the corresponding connectors. It can be seen that the terminals are clustered around the port area of Hampton Roads, Richmond, Roanoke, and others scattered along the I-81 Corridor and Northern Virginia.



Source: Bureau of Transportation Statistics, Virginia DRPT, and Federal Railroad Administration.

Figure 8. Existing Intermodal Terminals with Rail Access

Speaking of the prioritization process and ranking matrix, the document states that the current process in Virginia already captures several of the key items related to the benefits of public investment in railroads. The main benefits considered are number of jobs created and reduced transportation costs. As project size, complexity, and costs increase, there is a need to demonstrate more direct and tangible benefits to sell railroad projects to the general public. The public is looking for improved travel times, reduced highway congestion, reduced highway costs, improved safety, improved environmental quality, lower taxes, and lower prices in retail stores. Another item that must be considered when evaluating projects is the source of the funding.

The document suggests that the process and evaluation of allocating public funding to freight rail projects for congestion mitigation, avoided highway costs, or other purposes is not well established. In order to justify public investment in private freight railroads, it will be necessary to quantify the benefits. The document provides a broad framework for such project evaluation and ranking by providing public benefit criteria (See **Table 4**).

Table 4. Specific Public Benefit Criteria for Public Investment in Rail Projects

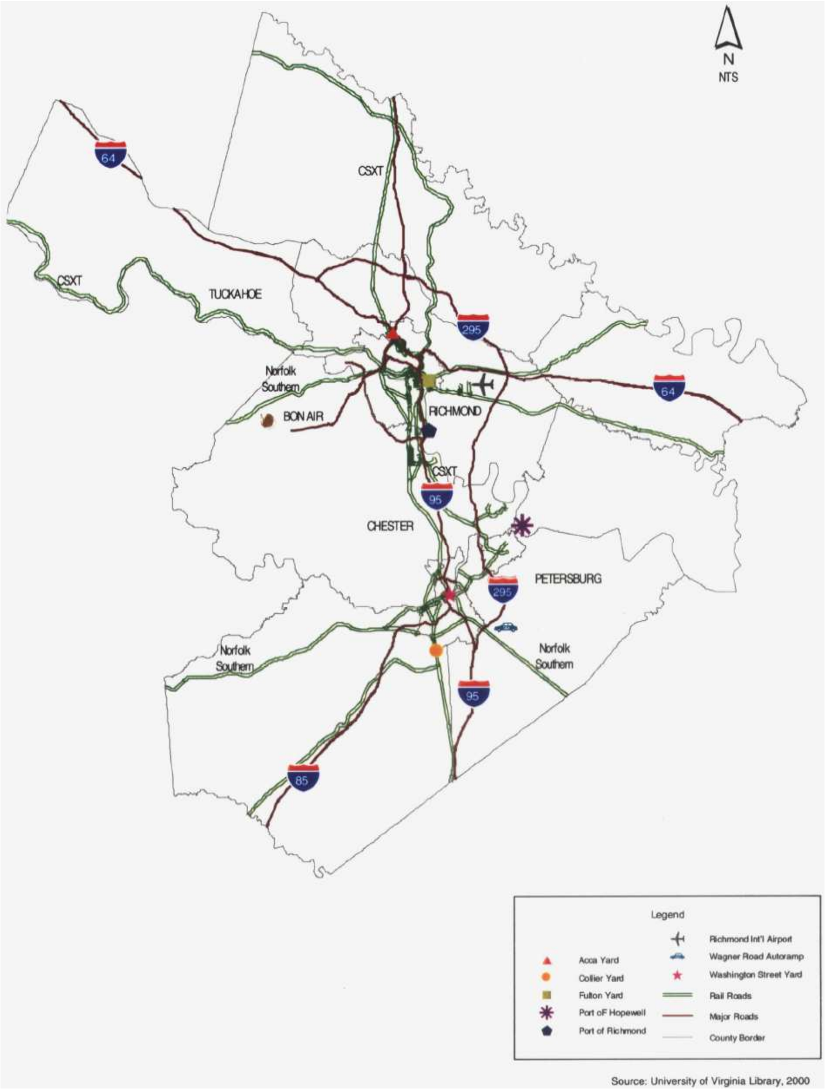
Sl No	Public Benefit Criteria*
1	Safety, security, maintaining overall state of good repair.
2	Improved capacity and service speed, reliability, and availability.
3	Improved transportation choices and intermodal connections.
4	Increased employment, business competitiveness, and local tax base through industrial attraction and expansion.
5	Congestion mitigation and improved air quality.
6	Cross-modal benefit/cost and ability to work in tandem with highway investments (through avoided or reduced highway construction and maintenance costs).
7	Viability and sustainability of private commitment to meeting performance goals related to public investment.

* Not intended for detailed project-level evaluation

2.5.3 Richmond Area Freight Study

This study addressed ways to enhance the economic competitiveness of the Richmond Metropolitan Planning Region by enhancing freight movements through the region and investigated the possibility of a future intermodal transportation facility to improve the linkages between highway, rail, air and ports [35].

Considering the transportation system (See **Figure 9**), three interstate highways (I-95, I-64 and I-85) and numerous other major roadways are present in the Richmond-Petersburg area. Two Class I railroads offer service to the region. An international airport is also present as well as a port facility on the James River. Regionally, numerous trucking firms have a presence in Richmond due to its geographic location. Richmond is a regional trucking center, servicing the needs of many distribution centers, manufacturing and service organizations. Thus, trucks form large percentage of current volumes on portions of I-295, I-95 and US-460. The heaviest overall volumes are on I-95 and portions of I-64 (west) and I-295 (south), portions of US-360 and US-460 also carry high truck volumes.

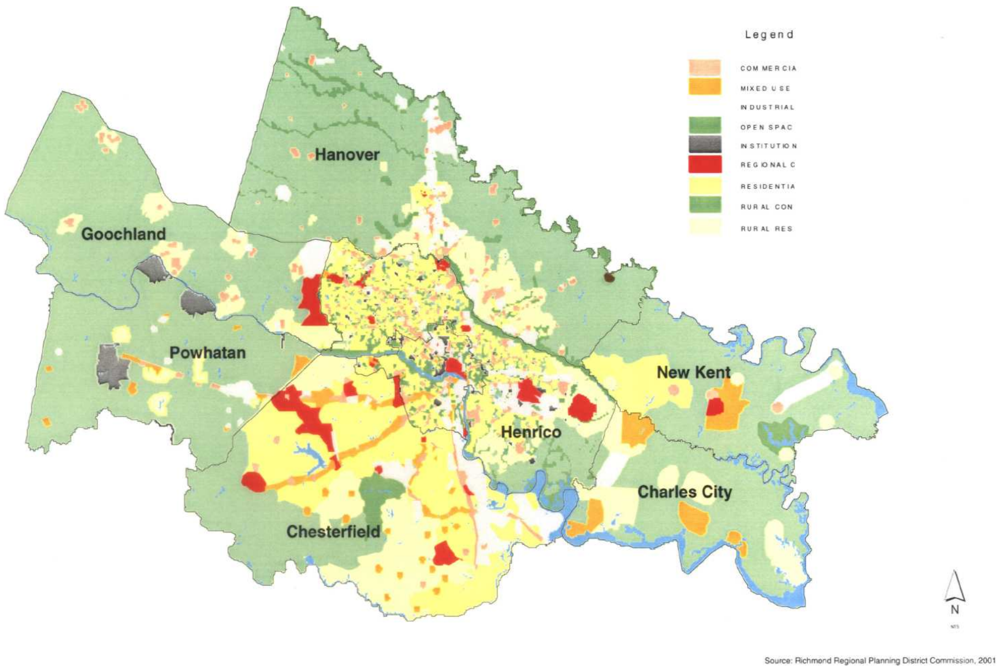


(Source: Richmond Regional Intermodal Transportation Study, 2001)
Figure 9. Location Map for the Richmond-Petersburg Area Intermodal System

Speaking of railroads, CSX is the principal railroad in Richmond, with mainlines both east-west and north-south. On the other hand, the Norfolk Southern's principal north-south line runs through the Shenandoah Valley and Front Royal to the west of Richmond. Their major coal line, which connects the coal producing regions in West Virginia to the Port of Norfolk, passes through Petersburg. The NS line serving Richmond passes through the downtown section of the City of Richmond, crossing the James River on the fall line. A branch line from Richmond terminates at the port of West Point on the York River, which empties into the Chesapeake Bay. The study suggested that the use of rail to move freight in the Richmond region is unlikely to grow substantially, especially relative to the expected growth in trucking. The factors that could increase the forecast include the incorporation of an intermodal facility in the Richmond area, increased demand for coal, or significant upgrades in the speed and reliability of rail service.

The document discussed the demographic trends and land use (See **Figure 10**), at State level as well as that for the Richmond-Petersburg Metropolitan Statistical Area (MSA). It found that changes in spatial growth of the population in both a regional and a national context are creating shifting demands for certain modes, primarily highway usage. The industrial areas within study area were also found to be predominantly located adjacent to the major through highway routes.

The study also investigated feasibility of an intermodal facility and its potential locations. As a part of this, the shippers, truck carriers, air cargo providers and private rail companies were surveyed. The focus of this effort was on estimating the number and type of trips that will be attracted to use the new facility, i.e. developing scenarios of freight forecasts. The impacts of developing new intermodal facilities were not evaluated. The rail service providers indicated no desire for an intermodal facility at the time of the study. The study recommended based on their findings that the conditions did not warrant the immediate development of an intermodal facility. There was also competition identified from other existing intermodal facilities, located at Baltimore and Charlotte. No specific cost estimates or improvement plans were outlined. The study recommended development of a process for gauging comprehensive intermodal demand and developing a set of sufficient conditions that when met, would call for the development of an intermodal facility.



(Source: Richmond Regional Intermodal Transportation Study, 2001)
Figure 10. Land Use Map for the Richmond-Petersburg MSA

2.6 Available Databases

There are several sources for freight flow data [36]. Based on the applicability, availability, access and accuracy for the evaluation of system impacts, few of these have been selected. Due to the nature of impacts being studied (Refer to **1.3**), information other than the freight flows is also essential. The complete list of databases that was found useful for the Study is described in this section:

(1) Oak Ridge National Laboratory (ORNL) GIS Database

According to documentation for the database, the Oak Ridge National Highway Network (NHN) is a geographically based analytic network of major highways in the United States stored in the form of a database [37]. Data included in this network come from several sources, including USGS National Atlas Digital Line Graphs (DLGs), State Maps, Other Maps (1:250,000 and 1:100,000 scale USGS maps), Highway Performance Monitoring System (HPMS) for attribute information, Defense Movement Coordinators, TIGER/Line Files for roads not represented in the DLGs, Digitization of Urban Area Maps, and NHPN version 2 for geographic shapes, functional classes, and National Highway System flags. The database is useful to perform network analysis and to visualize evaluated impacts. It was provided along with the Global Insight, Inc.'s (GII) TRANSEARCH Database.

The factors that degrade geographic (or locational) accuracy are: (a) Centerline representation: When separated directional roadways were far enough apart to have distinct alignments in the DLGs, one of those roadways (invariably the shortest) was chosen to represent both directions of travel; (b) Interchange representation: Interchanges and traffic circles are almost always represented by a single point, or node. Ramps are explicitly included in the NHN only when they are long enough; (c) Straight-line links (shape information not considered); and

(d) No source data exists: Many new roads in the NHN do not have representations in either the DLGs or TIGER.

The factors that have an impact on topological accuracy are: (a) Non-planar: A route which passes over another without any connection that traffic can use will be represented without a common node at the crossing; (b) Explicit ramps: Most interchanges are represented by a single node at the intersection of centerlines. However, if this misrepresents the average distance of travel through the interchange by more than a half kilometer or so, the interchange will be decomposed into multiple links and nodes; (c) Notional ramps: Especially in congested areas, it sometimes happens that a common set of ramps will serve to connect an expressway with several nearby surface streets. Rather than have separate nodes at the crossing of the expressway with each street, a single node along the expressway will represent the “interchange” and links will run from this node to surface street intersections.

(2) Global Insight, Inc.’s (GII) TRANSEARCH 2004 Database

This data was provided by Virginia Department of Transportation for conducting the Study and is useful to estimate several of the systemwide impacts. According to TRANSEARCH documentation that accompanied the database, it is an annual, nationwide database of freight traffic flows between US county or zipcode markets, with an overlay of flow across infrastructure. The database draws from data sources indicated in **Table 5**.

The procedure begins by establishing State production volumes by industry or commodity. This information is drawn from the Census Bureau’s

Annual Survey of Manufactures and the Census of Manufactures. Both of these sources report production in dollars, which are converted to tons using commodity value/weight relationships maintained by GII. Tonnages moving by rail, water, air, and pipeline are netted from the totals (which serve as control totals), leaving the remaining freight volumes allocated to truck distribution patterns. Export volumes are developed by the same procedure. Import volumes, drawn from US Department of Commerce data, are subsequently combined into the traffic flows at the point of importation. Separate databases for NAFTA traffic are produced and offered in conjunction with the US data set. Carload and intermodal trailer-on-flat-car/container-on-flat-car (TOFC/COFC) traffic are maintained as separate volumes. For much of the intermodal traffic, the commodity is identified only by the general classification FAK (Freight All Kinds).

Table 5. Data Elements used in Developing Production-Consumption Patterns

Sl No	Database	Used for Estimating Modal Flows
1	US Dept of Commerce Census/Survey of Manufacturers	Truck, Water, Air
2	GII Industrial Production Indices	Truck, Water, Air
3	Trade Association Production & Shipment Reports	Truck, Water, Air
4	US Geological Survey Mineral Industry Reports	Truck, Water
5	Global Insight, Inc. (GII)/InfoUSA Street-Address Industrial Employment & Activity	Truck
6	County Population Data	Truck
7	Inter-Industry Trade Patterns (Input Output Table)	Truck, Air
8	Motor Carrier Industry Financial & Operating Statistics	Truck
9	Railroad Industry Proprietary Traffic Factors	Truck
10	Private Port Directories	Water

Secondary traffic in TRANSEARCH is divided into warehouse and distribution traffic, and drayage. Air and rail intermodal freight fall under the latter category. Special definitions of STCC Codes uniquely identify these movements. Three sources of information are used in estimation of the warehouse and distribution center flows. First, shipments inbound to markets, combined with input/output tables and analysis of certain aspects of the CFS give a preliminary picture of volumes. Then, locations of warehouse facilities are compiled from street-address establishment data and information provided by the Public Warehouse Association. Based on employment levels and facility size where available, GII algorithms are applied to estimate output. Third, portions of data from the Motor Carrier Exchange program are used to calibrate distribution patterns. After developing linkages between production and transportation flows, the flows are routed using ORNL algorithm that selects a single, lowest impedance path between any pair of counties. Impedances reflect distance, class of highway and travel speed, and tolls. Routing for other modes is carried out using Global Insight, Inc.'s own routing models.

(3) *Census Bureau State and County Quick Facts*

Few of the demographic and economic data were available online and the gathered data include population as in 2006, land area as in 2000 and per capita income as in 1999 for counties in the Commonwealth of Virginia. Other county related economic variables like wholesale trade and retail sales, manufacturer shipments, etc. are found to be less useful as many a times that data is suppressed to avoid disclosure of confidential information.

(4) *IMPLAN County Wise Employment Data*

This data was available from previous studies conducted at Center for Transportation Studies at University of Virginia. The year of the data is 1999 and is in the form of county wise and sector wise employment and employment growth rates. It provides details on the transportation related employment, a sum total of employment in motor freight transportation and warehousing, water transportation, transportation by air and transportation services.

(5) *Virginia Department of Transportation's (VDOT's) Crash Database*

This database was made available by the Virginia Transportation Research Council and provides information on crashes by functional class of highway, vehicles involved and location (i.e. close to or away from intersection) within the Commonwealth of Virginia.

(6) *VDOT's GIS Integrator*

The GIS Integrator is a GIS interface to view enterprise business data (such as accidents, traffic volumes, construction project information and assets) together in an easily accessible format, using the web browser on the desktop. It was also made available by the Virginia Transportation Research Council. It enables data to be dynamically viewed and queried in relationship to other data on a location-referenced map. This database is useful in providing traffic related information for rough link travel time estimation.

(7) *2005 Rail Waybill Sample*

The annual Rail Waybill Sample is developed by the Association of American Railroads (AAR) under contract with the Surface Transportation Board

(STB). It is in the form of a single ASCII coded data file. The Public Use version consists of 247-byte records and captures detailed information on total rail traffic, commodities, revenues, origin-destination flows, and routing information. This data was purchased from the office of Surface Transportation Board. The aggregation of flow data is done to Bureau of Economic Analysis (BEA) level. Annual statistics for railroad shipments in terms of number of carloads, shipment tonnage, and revenue of railroads for each sampling category are computed using an expansion factor defined by the ratio of the population to the sample size. This database, in conjunction with the GII TRANSEARCH database, is useful in performing truck-to-rail diversion analysis based on revealed preference.

CHAPTER 3: METHODOLOGY AND DATA COLLECTION

3.1 Basis for the Framework for Evaluation of System Impacts

The previous chapter described the vital infrastructure and technology that an intermodal terminal project provides, and ideally speaking how it can act as a cost and service alternative in promoting the competitiveness of intermodal transportation relative to truck-based transportation. The characterization of intermodal terminals helped identify issues related to the measurement of project impacts and select variables for modeling purposes.

The existing reports indicated that the evaluation of intermodal terminal projects based on their impacts has several advantages to the public agencies and the private firms. For example, the VDRPT can assess the need for public sector involvement in rail freight projects, the VDOT can learn the extent of reduction in congestion on the highways and the Metropolitan Planning Organization can determine the effect on regional economic development due to addition of a transportation choice. Finally, the private stakeholder such as a rail company or a shipper can compute profitability due to expansion of the intermodal business. The methodology proposed in this Study combines the various public and private sector benefits of the evaluation into a single impact analysis framework.

3.2 Steps in the Framework for Evaluation

The framework described in this section has been represented in the form of a flowchart in **Figure 11**.

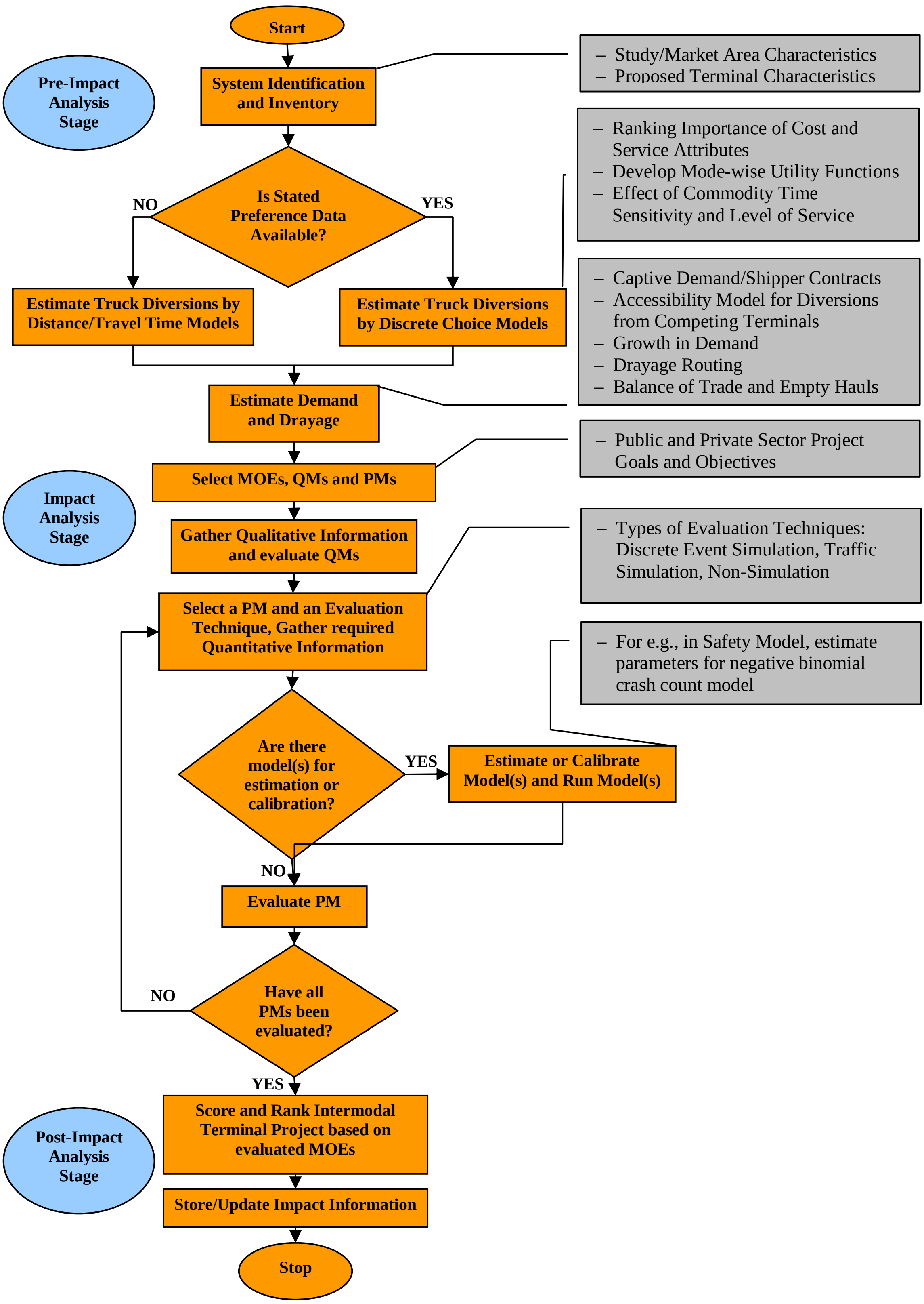


Figure 11. Flowchart for Evaluation of System Impacts

As the flowchart shows, the steps and tasks associated with the framework can be divided into three stages, namely, pre-impact analysis, impact analysis and post-impact analysis. The components of these three stages are described in the following sub-sections.

3.2.1 System Identification and Inventory

In this step information about the project terminal, its market area and competing terminals is collected and includes the following tasks:

(1) Determine scope, purpose and project details of the proposed terminal based on information gathered from project proponents and public agencies involved.

(2) Assess characteristics of the proposed location of the intermodal terminal, such as land use, industrial developments, physical infrastructure, etc.

(3) Identify a study area that includes location of the intermodal terminal, its potential market outreach, and locations of competing rail-truck intermodal facilities. The study area should consist of as small analysis zones as possible for improving accuracy of freight traffic analysis. The analysis zones may be defined differently for different types of analysis in this framework.

(4) Identify key commodities entering or leaving or passing through the study area.

(5) Collect existing truck and rail intermodal commodity flow and intermodal truck drayage information for flows with either origin or destination in the study area and as related to purpose of the project.

(6) Collect information on demographic and economic variables such as population, per capita income, employment and industries that can be linked with freight flows amongst the analysis zones of the study area.

It is assumed that competing direct trucking facilities are uniformly distributed over the entire study area and do not need any special identification.

3.2.2 Obtaining shipper requirements and preferences

In order to realistically estimate demand, a stated preference survey of the shippers in the study area needs to be conducted. Danielis and Rotaris, and Wardmam discuss some of the inherent benefits of the stated preference survey over the revealed preference approach of transportation demand estimation ([38],[39]). Types of information that can be collected in such a survey include:

(1) Perception of study area shippers about intermodal transportation;

(2) Type of industry, types of commodities transported, commodity characteristics transported using intermodal units;

(3) Service requirements, willingness to pay and willingness to accept; and

(4) Logistic costs incurred due to time sensitivity of shipments.

The Study does not discuss details on modeling of the choice process using the stated preference survey data. It is however pointed out that multi-criteria analysis models can be built on the stated preference data which in turn can yield the utility functions of the choices [40].

3.2.3 Estimating demand and drayage

As already discussed in **2.2.1**, an intermodal terminal very rarely is the sole mode available for transportation of freight in a region. It is set in a competitive setting with several trucking firms and other intermodal terminals. In some cases, long-term shipping agreements with the competing intermodal and/or direct trucking agencies disallow shift of business to a new terminal. The shippers may also need to incur expenditure to establish infrastructure such as warehousing or a containerization facility in the vicinity of the new terminal. Lastly, not all types of freight can be moved in rail intermodal units. Hence, the way to assign freight shipments of a region to an intermodal terminal and thereby estimating its demand is very complicated. In this Study, individual shippers in the analysis zones could not considered due to macroscopic nature of the traffic and economic data used.

In absence of market analysis data from the railroad company and the stated preference survey data, the demand and drayage assessment step consists of the following tasks:

(1) For diversions from existing intermodal facilities,

(a) Using the network analysis module in GIS software (ArcGIS Version 9.0 used in this Study), determine the shortest major access routes between the study analysis zones and the intermodal facilities (including the proposed facility). Then compute volume-to-capacity (v/c) ratios over all the links on these routes. For evaluation purposes, estimate access times on the identified routes using a modified Bureau of Public Roads (BPR) curve with the equation as shown below [41]:

$$t = 60\left(\frac{l}{s_f}\right)\left(1 + 0.2\left(\frac{v}{c}\right)^{10}\right)$$

where t = link travel time in minutes;

l = link length in miles; and

s_f = free flow speed in mph

Better prediction equations for travel times under congested and uncongested, interstate and non-interstate conditions have been developed in the literature. In an effort to incorporate some of these variations, the following free-flow speeds were used in this Study: (a) Rural Interstate: 65 mph; (b) Rural Principal Arterial: 60 mph; (c) Urban Interstate or Rural Minor Arterial or Rural Major Collector: 55 mph; (d) Urban Freeways and Expressways: 50 mph; and (e) Urban Principal Arterials and Major Collectors: 45 mph.

(b) Estimate the diversion of intermodal freight traffic to the proposed intermodal terminal from a competing facility using a two-stage accessibility model. It is assumed that tons of freight to a terminal in relative terms is reflective of the choice probability of that terminal for a particular analysis zone.

In the first stage, a multinomial logit model based on maximum likelihood estimation for the terminal choice probabilities of the existing set of competing terminals is fitted. The model uses scaled travel time deviation, $t_i^s = \left(\frac{t_i - t_{med}}{t_{med}} \right)$, as an explanatory variable. Here, t_i refers to travel time to terminal *i*, and t_{med} is the median travel time for all of the existing terminals.

Based on (a) above, the number of observations used for the model estimation will be a product of the number of analysis zones and number of existing competing facilities. The multinomial model consists of the following (n-1) generalized logits of marginal probabilities:

Multinomial Logit: $\ln\left(\frac{\pi_i}{\pi_n}\right) = \beta_{0i} + \beta_{1i} t_i^s + \varepsilon_i$, i = 1,2,...,(n-1) **(1)**

where, π_i = percentage of market captured by terminal *i*

π_n = percentage of market captured by terminal *n*, i.e. last in an ordered sequence of terminals

Other potential explanatory variables that could be added in **Equation (1)** include available area, employment, pricing, level of service, etc., which are the terminal characteristics.

It can be seen that multinomial regression results in (n-1) sets of parameters, which is not convenient for prediction of flows to a new or proposed terminal in probabilistic sense. Hence, after checking for goodness of fit of the model in the first stage, a second stage model is proposed. Here, a Pooled Ordinary Least Squares (POLS) regression is carried out between the logistic function estimates $\left(= \ln\left(\frac{\pi}{\pi_n}\right)\right)$ from the first stage model and all of the scaled travel time deviations to obtain a common estimate of the parameter set (β_0, β_1) for all terminals. The equation used is shown as follows:

POLS: $\ln\left(\frac{\pi}{\pi_n}\right) = \beta_0 + \beta_1 t^s + \varepsilon$ **(2)**

Now, the new terminal data is included and the t_{med} is recalculated to obtain new t_s^i values leading to revised choice probabilities. The outcome is that the drayage requirements from/to the analysis zones within the study area to the proposed terminal are estimated.

(2) For truck-to-rail diversions,

(a) Group the analysis zones closer to the new terminal into a single analysis zone. This is done for convenience of modeling mode choice for long-haul movements.

(b) Select analysis zones which lie close to the rail corridor (that serves also the new terminal) and have a maximum drayage distance of about 200 miles. Also, select these analysis zones such that they are beyond 500 miles by distance over highways from the centroid of the analysis zone derived in (a). The reason for choosing 500 miles is that this is a distance that can typically be covered over a highway in one day by a truck. Effectively in this Study, truck-to-rail diversion analysis is performed only for truck freight taking longer than one day.

(c) Estimate the commodity flows which can be transported between the analysis zones derived in (a) and (b), while screening out the commodity types that are highly mode specific.

(d) Gather mode choice attribute information such as distance/cost, travel time, reliability etc. for both truck and rail.

(e) Estimate the freight traffic diversion from truck to rail by use of a mode choice model. The options for modeling the mode choice include the binary logit and the Ordinary Least Squares (OLS) regression (with a model structure similar to the binary logit). Due to the grouping, selection and screening processes, the number of analysis zones comes down drastically for this type of diversion analysis. Thus, binary logit model cannot be confidently applied. Therefore, for analysis zones with non-zero truck and rail freight movements, OLS regression between logarithm of the ratio of truck to rail total flows and any of the individual mode choice attributes is suggested. In this Study, the difference between distances by truck and rail is the explanatory variable used in the model. The distance by rail also includes the drayage. The equation relating the variables is as follows:

$$\text{OLS: } \ln\left(\frac{TruckTonFlow}{RailTonFlow}\right) = Intercept + \beta_1 (DiffDist) \quad \textbf{(3)}$$

The model is estimated using existing mode split and mode wise distances. It is then used to predict the new mode split considering the new terminal location. As a result the percentage change of freight flows to/from the analysis zones that are located away from the study area is estimated.

(3) Future demand and drayage,

Repeat the steps (1) and (2) for forecasted freight traffic, as provided in the commodity flow databases to predict future scenario.

Once the demand and drayage for freight from/to each analysis zone is ascertained, obtain the change in truck flows by routing the model results between centroids of these analysis zones or by superimposing them over the study area's road network after applying the estimated percentage changes to the truck flows.

Although empty hauls is another critical component of the demand assessment step, it is not modeled in this Study. As explained in **2.2.1**, the empty hauls are an outcome of a complicated series of activities taken up to reduce the gap between inbound and outbound traffic. In addition, operational policies and level of coordination followed by the railroad company and the shippers affect the number of empty haul miles. It is a topic considered for future research. For the Study, it is assumed that the rail company and the shippers will follow best industry practices (Refer to **2.3**) in communication and coordination to minimize the empty hauls.

3.2.4 Selecting and Evaluating MOEs (Qualitative Measures (QMs) and PMs)

After identifying the key decision alternatives in an intermodal terminal project that needs evaluation, it is necessary to select and standardize the MOEs to be considered in an evaluation of a project alternative. It is also necessary to allow comparability of the intermodal project with other freight projects. To overcome the problem posed by individual public agency and private stakeholder interests, it is suggested to use a common set of goals and objectives for establishing the MOEs, QMs and PMs. Since, the VTrans2025 goals and objectives are a result of a joint effort of several public agencies; these formed the basis for establishing the MOEs. The private stakeholder perspective is incorporated indirectly through the definitions of the MOEs. The comparability issue gets addressed because other freight projects can also be evaluated based on the VTrans2025 goals and objectives.

The global set of MOEs along with their qualitative and quantitative measures (PMs) has been described in **Table 6**. The choice of these measures is based on their applicability to a wide variety of intermodal terminal projects, practical relevance, and compatibility with public and private data collection. Among the comprehensive list of measures for evaluation of intermodal terminal projects some are meant for a planning stage evaluation and others for an operations stage evaluation. Hence, depending on stage of the evaluation and resources available with the agency conducting the evaluation, a suitable list of measures can be selected from this master list.

The QMs as described within the list of MOEs can be evaluated by use of survey instruments or interviews, use of checklists, site visits and review of project documents.

In connection with the established PMs, the estimation procedures can be broadly classified as simulation based and non-simulation based. The simulation based techniques include discrete event stochastic simulation of the terminal operations and microscopic traffic simulation of the landside operations. As a result of the data intensive nature of the simulation techniques they are rarely used for intermodal terminal projects with a small scale investment. Some of the implemented discrete event stochastic models were identified in literature ([42],[43]). Due to the limitations on time for the Study, modeling aspects of the two types of simulation techniques have not been further investigated.

Table 6. MOEs, QMs and PMs for Intermodal Project Evaluation

MOE	QMs	PMs
Improve safety related to truck, shipments during transit and routes for hazardous materials	• Identify truck routes, restrictions, and routes for hazardous materials • Check condition of equipment and human skill levels for containerization and material handling at the terminal	• Estimate change in truck involved crash rates on regular truck routes and routes for hazardous materials used for drayage • Compliance rates on truck restrictions by drayage truckers • Percentage of damaged shipments by value
Improve security of shipment using tracking, and check-in and check-out procedures	• Check accuracy and robustness of shipment tracking technology • Check soundness of shipment identification procedures	• Number and value of shipments that failed to reach destination annually • Number of unidentified or wrongly identified shipments annually
Handle strategic and emergency transportation needs such as excessive demand, equipment failure and roadside congestion	• Check availability of repair tools and spare parts • Check availability of standby equipment and staff • Check availability and quality of routing information	• Estimate equipment repair/replacement time • Estimate instantaneous spare capacity in terms of TEUs that can be handled at the terminal • Estimate travel time savings due to routing information per drayage truck-mile
Minimize capital, operational and maintenance costs (i.e. lifecycle costs) for the terminal	• Identify site type for development (Greenfield or Brownfield) • Identify equipment type (purchase or lease) • Check use of any planning and coordination techniques for pickups and deliveries	• Estimate cost for land and development • Annualize cost of equipment • Estimate annual cost of operations • Estimate annual drayage costs • Estimate annual energy costs at the terminal • Estimate annual routine and periodic maintenance costs
Preserve intermodal transportation infrastructure	• Check age and condition of the equipment • Make qualitative assessment of pavement condition along the truck routes	• Estimated change in total truck ton-miles • Assess practical capacities of equipment • Measure roughness, surface distress, skid resistance and deflection on the truck routes

MOE	QMs	PMs
Manage land side access for the shippers using the terminal and coordinate with the local land use policies	• Check availability of land for future terminal expansions • Predict changes in the land use pattern • Assess impact of the local land use policies on the terminal • Nature of access control on the truck routes	• Estimate change in land value, population density and per capita income • Estimate change in percentage of local passenger trips on the truck routes • Estimate changes in travel time per drayage truck-mile
Maximize terminal system utilization by managing terminal space, equipment and operations	• Assess extent of segregation of terminal space and activities • Identify pickup or delivery policy followed • Identify type of equipment and transfer technology used • Check human skill levels for handling specialized functions • Assess nature of fluctuations in demand over time • Identify type of communication technology • Check use of various levels of service	• Estimate average check-in and check-out time losses per shipment per service type • Estimate average dwell time per shipment per service type • Estimate average shipment transfer time per service type • Estimate equipment transfer time losses over a unit period of time • Estimate idle time losses of equipment over a unit period of time • Estimate number of empty hauls per shipment per service type
Reduce congestion on highways and minimize impacts on the capacity for movements of people and goods	• Identify highway capacity improvements resulting from terminal development • Identify changes in the pattern of truck flows • Identify major activity centers (residences, work places, markets, etc.) affected by drayage trucking	• Estimate change in ton-miles of drayage truck flows • Estimate change in ton-miles of non-drayage truck flows • Estimate change in vehicle-hours of travel on the truck routes and routes connecting major activity centers
Minimize impacts on the capacity for existing rail movements	• Identify affected rail corridor and terminals • Change in frequency and flexibility in rail service	• Estimate change in travel time per train between the identified terminals on the affected rail corridor due to increase in number of trains and passing maneuvers

MOE	QMs	PMs
Expand modal choices and provide cost/service alternative for economic development	• Identify shippers benefiting from the terminal • Check availability of land in the vicinity of the terminal for locating warehouse and distribution centers	• Estimate benefit-to-cost ratio to shippers using the terminal • Estimate TEUs of freight handled at the terminal • Estimate increase in transportation related employment • Estimate change in warehouse related freight movements
Minimize the environmental impacts	• Identify attainment and non-attainment areas with regards to harmful emissions • Identify noise sensitive areas • Identify water bodies that are likely to be contaminated • Identify affected lands, wildlife and habitations • Identify cultural and historical resources affected • Identify mitigation measures for the environmental impacts	• Estimate change in the emissions of harmful gases and particulate matter on the truck routes • Estimate change in noise level on the truck routes • Estimate change in BOD levels of affected water bodies • Estimate areas of farmlands, wetlands, forests, etc. lost to the development of the terminal • Estimate overall environmental impact mitigation costs
Maximize the benefits of investments into intermodal terminal	• Assess investment recovery strategy • Assess pricing strategy for rail and drayage service	• Estimate internal rate of return to rail and drayage company • Estimate social rate of return to public agency
Make planning, coordination and funding of interdependent multimodal projects effective	• Check use and type of innovative funding mechanisms • Check use of staging or phasing opportunities in the intermodal project	• Difference between actual and planned cost and time of completion of the intermodal project

The remaining part of this section provides description of the non-simulation based techniques used to evaluate some of the PMs as follows:

(1) Safety

Using truck involved crash statistics, models for fatal, injury and PDO (property damage only) non-intersection type crashes are built for different functional classification (interstate/non-interstate) and location (urban/rural). For modeling convenience the fatal and injury type crashes are combined with PDO type crashes, using weighting factors of 9.5 and 3.5, respectively. Number of crashes is estimated using log of Annual Average Daily Traffic (AADT) and length of segment as explanatory variables. In this Study, pre-defined relationship of negative binomial between dependent and independent variables is used for regression. By considering the truck routes and routes for hazardous materials, the corresponding changes in truck involved crashes can be estimated.

(2) Mobility

Mobility as described in **2.2.4** refers to the movement of people and goods. It is typically measured in terms of travel mileage and speeds [44]. For the purpose of evaluation, change in mobility is measured as the estimated change in annual ton-miles of drayage and non-drayage truck flows. The value is deduced from the estimated change in demand and drayage (Refer to **3.2.3**), and routing onto the study area road network.

(3) Accessibility

Accessibility as described in **2.2.5** refers to the ability to reach desired goods, services, activities and destinations (collectively called opportunities). It is typically evaluated based on the time, money, discomfort and risk required to reach opportunities [44]. For the purpose of evaluation, change in accessibility is measured as the estimated change in annual drayage truck-hours in the study area using the competing intermodal terminals. Its value is deduced from the estimated changes in the drayage traffic and travel times on the study area road network.

(4) Land Use and Secondary Local Passenger Traffic

Several integrated land use and transportation models have been developed in the past, such as ITULP (DRAM/EMPAL), MEPLAN, TRANUS, METROSIM, UrbanSim, etc. These models like the simulation models are data intensive. Comparison of various land use models can be found in NCHRP Report 466 as well as in the work by Waddell ([19],[45]). Provided the past trends in land use, land value, population density, per capita income and the travel cost matrix for the study area is given, it is assumed that an existing land use model will be able to provide information on change in passenger trips which can then be superimposed on the changes in truck trips in the study area from the demand analysis (Refer to **3.2.3**).

(5) Economic Development and Secondary Local Freight Traffic

In order to measure the economic development impacts of a transportation investment, use of input-output modeling tools such as REMI (Regional Economic Models Inc.), IMPLAN (a model developed by Minnesota IMPLAN Group) is common. The tools estimate the impacts of policy decisions on demographic and economic variables. Assuming that the effect of an intermodal transportation investment on the population density, per capita income and transportation related employment are known, a linear regression model that links these primary impacts to the secondary impacts of local warehouse and distribution center freight flows is proposed as follows:

$$\left(\frac{WareTrkTons}{Area}\right) = Intercept + \beta_1\left(PopDens\right) + \beta_2 PCI + \beta_3\left(\frac{TranEmp}{Area}\right) \qquad \textbf{(4)}$$

Where,

WareTrkTons =	Warehouse and Distribution Center truck tons originating or terminating at analysis zone (tons)
Area =	Area of analysis zone (sq miles)
PopDens =	Population Density (per sq mile)
PCI=	Per Capita Income ($)
TranEmp=	Transportation Related Employment

The modeling effort when used in conjunction with the input-output models helps the public agencies understand the significance of secondary freight traffic impacts and identify areas of concern by superimposing these trips upon the changes in truck trips in the study area from the demand analysis (Refer to **3.2.3**).

(6) Profitability to Shippers

Benefit-to-cost ratio to the shippers is determined by taking a ratio between the new drayage and rail transportation costs incurred in the proposed setting to the cost savings in the existing truck flows.

(7) Changes in Environmental Setting

Based on the freight flow analysis in this Study and information about typical terminal operations, environmental studies can be conducted for the corresponding impact assessment.

(8) Preservation and Management

At planning stage the estimated change in total truck ton-miles can be used as a practical measure. Some of the PMs that can be monitored on continual basis during the operations stage such as the compliance rates of drayage truckers on the truck restrictions, percentage of damaged shipments by value, number of misdirected or unidentified or wrongly identified shipments annually, measurements of pavement condition on the truck routes used for the drayage.

3.2.5 Combining different MOEs into a single score for ranking purposes

As it can be seen from the **Table 6**, the impacts are being measured based on the VTrans2025 goals and objectives derived from VTrans2025. Since, these form a common basis for all freight and public transportation projects in Virginia, a suitable scoring mechanism can be formulated wherein the contributions of each MOE in achieving the corresponding goals or objectives are evaluated by the staff of public agencies and private stakeholders. The comparison of project evaluations can be limited to those within a particular multimodal investment network (MIN). Additional work needs to be carried out in determining the weighting matrix for MOEs under a particular objective and is not within the scope of this Study.

3.2.6 Storage, retrieval and updating of impact information

As a final step of the evaluation framework, impact information generated by the various models is proposed to be stored in a suitable format for easy retrieval and future use. One such beneficial tool is the Geographical Information System (GIS). It allows analysis and selective visualization of the impacts. Depending on type of evaluation technique used and data compatibility, other techniques of storage may also be used.

CHAPTER 4: CASE STUDY AND RESULTS

4.1 Scope of the Case Study Evaluation

The framework for evaluation developed in Chapter 3 covers a wide range of planning and operational measures. However, the objective of this analysis was not to evaluate all of these measures for the case study project, but to use interviews, commodity flow databases and other available resources to public agencies to conduct an evaluation of a location decision for a proposed truck-rail freight intermodal terminal in terms of certain systemwide impacts, including safety, mobility, accessibility, economic development, shipper profitability and highway system preservation and management. The analysis was performed using database, statistical and GIS-based techniques.

4.2 Case Study Related Interviews

In this Study, interviews were conducted with the Regional Planning Agency, the Railroad Company, the Local Government and the State officials to gather information regarding development of the case study facility and the public and private sector involvements.

4.2.1 Crater Planning District Commission (CPDC)

In order to understand the regional perspective about the intermodal terminal project, the Crater Planning District Commission (CPDC) was interviewed. The CPDC is an agency charged with the mission of planning for the physical, economic and social development of 10 local governments in south central Virginia, south of the City of Richmond.

The agency was involved in the review of the 2001 Richmond Intermodal Transportation Study originally prepared for the Richmond Metropolitan Planning Organization (MPO). The key findings from this interview were as follows:

(1) Although the Tri-Cities MPO was aware of the proposed intermodal facility in Prince George County (near Petersburg, VA), it was not identified in the 2001 freight study as a potential site. Hence, evaluation of the proposed terminal near Petersburg, VA was not performed by the MPOs.

(2) The 2001 Richmond study findings were confirmed. Shedding light on a particular recommendation of that study, the CPDC pointed out that no committee for analyzing demand for rail-truck intermodal service has been formed so far.

(3) Speaking on freight concerns of member localities and current projects, it was learned that Prince George County was the only public agency which expressed concerns about increasing truck traffic on existing US-460 and also future traffic flows at the proposed western terminus of the new US-460 at I-295. It is realized that the proposed terminal project will have added impacts to those due to the US-460 improvements.

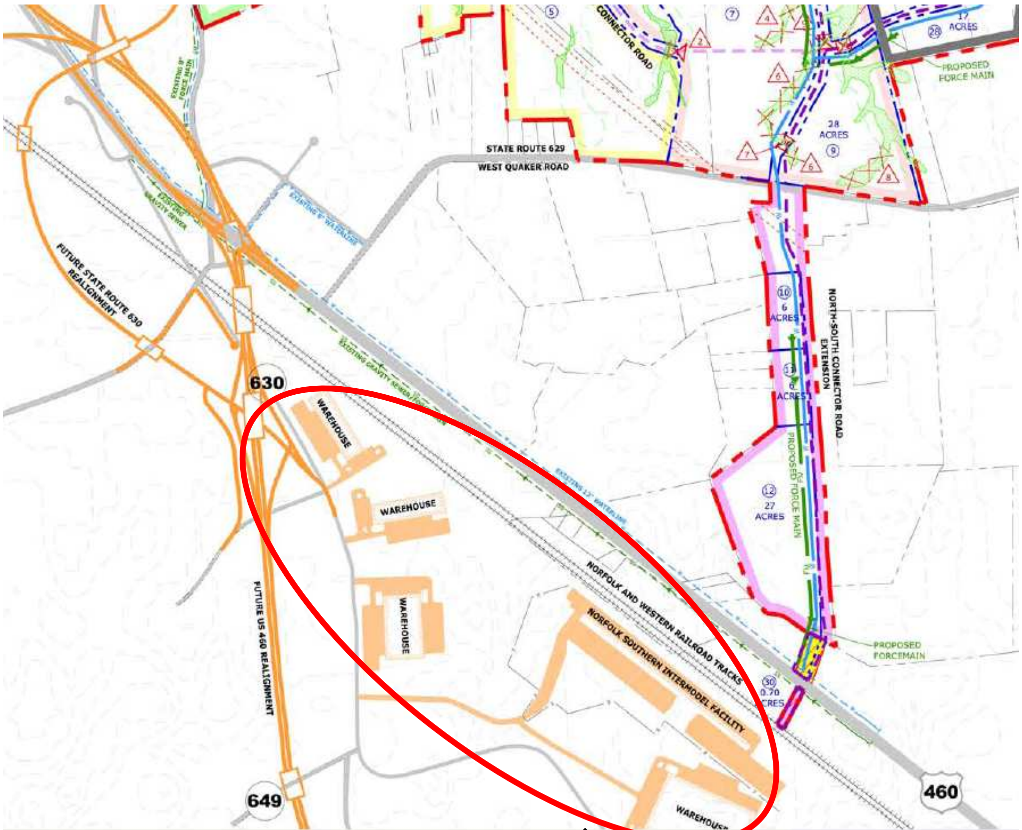
(4) The CPDC described recent actions by the VDOT to handle freight planning for the region as providing access to the Statewide freight flow data to MPOs, and getting the CPDC staff involved in a survey of 10 major shippers in the Tri-Cities MPO region for VTrans 2025.

4.2.2 Norfolk Southern Corporation (NS)

The interviews with the Norfolk Southern Corporation were conducted in two stages. The first of these interviews was conducted with the contact person in project development division of the intermodal department. In the second stage information was gathered from the marketing division of the same department. The findings from the interviews under each stage have been summarized as follows:

(1) *Project Development Division*

(a) The case study terminal is proposed to be located in Prince George County on Memorial Drive (State Rte 630), about 1 mile from the intersection with US-460 and is not planned to be built for another couple of years (See **Figure 12**).



(Source: Crosspoint Centre Master Plan↑, Courtesy: Timmons Group)
Figure 12. Proposed Location of the Study Terminal

↑ http://www.yesprincegeorge.com/documents/Crosspoint%20Centre%20Master%20Plan-small.pdf, a website belonging to the Department of Economic Development of Prince George County, VA, last accessed on November 30, 2007)

(b) The criteria used for selecting this location included presence of the Norfolk Southern mainline track, presence of intermodal train service, sufficiency of size and length of site along main line, i.e. frontage to track, proximity to major highways, lack of nearby grade crossings, low land acquisition cost, flat terrain, and minimal affect on wetlands.

(c) The location choice was not made based on any specific major shipper; however the region south of Petersburg, VA was identified as a potential market for intermodal freight transportation by the marketing division.

(d) The site selected is predominantly a Greenfield site, except for one or two properties which have already been sold to the rail company.

(e) The terminal is not really part of what is defined as Heartland Corridor project; however, the project will benefit from this facility as doublestacking capabilities will be made available at the facility.

(f) The physical characteristics of the terminal can be described as having an area of about 40 acres, one 2000 ft long loading track, and two 2300 ft long support tracks, about 170 trailer parking spots, a gate building, and a maintenance facility for container/trailer repairs. Additional land near the terminal has also been purchased for establishing warehouses and distribution centers in the future. Sideloaders will be used to load and unload containers. The planned capacity for the facility at the start of operations is 30,000 lifts per year, which according to the Norfolk Southern is relatively a small facility in demand, size and complexity of operations.

(g) The terminal will use Strategic Intermodal Management (SIM) System for handling operations, hand-held computers for waybilling, and shipment tracking electronically.

(h) Considering customers for the case study facility, the Norfolk Southern will play the role of a seller in a wholesale market, selling out their transportation services, mainly on contract basis, to steamship line companies, truckload companies and IMCs. Few individual shippers may also have contracts directly with the railroad company.

(i) At the start of operations, the largest share of market for the case study terminal is expected to be international in nature, i.e. west coast traffic that gets transferred at Chicago to move along the Heartland Corridor and to a small extent the east coast imports and exports. Domestic traffic will be moving from/to the Upper-Midwest region of US along the Heartland Corridor.

(j) Speaking on the coordination activities, the Norfolk Southern has reached agreements with the Prince George County on funding access road improvements and rezoning. To be specific, these funds will be directed towards improvements to the Memorial Drive, which is currently not truck friendly and needs rebuilding for half a mile and an intersection improvement.

(k) Rezoning is not required as such for the intermodal facility but for the area around the terminal to allow construction of warehouses and distribution centers, which form a natural fit with the intermodal facility. This is intended to reduce the drayage costs for the customers.

(l) The rail company also had discussions with the VDRPT regarding funding under Virginia's Rail Enhancement Fund, but at the end the funding sources were restricted to the Norfolk Southern's own corporate funds and that of Prince George County because the scale of investments is small.

(m) The nearest major highway, namely the US-460 is four-laned. Also, the case study facility being modestly sized it is expected not to generate humongous drayage traffic. Considering the combination of these factors, the highway is not expected to face serious congestion exclusively on account of the terminal. Also, being located along a commercial route, time restrictions on truck drayage operations may not apply in this region.

(n) The case study terminal is expected to generate direct employment in a small way, i.e. about 10 people working in a one-shift operation. The facility will also generate direct employment in warehousing and distribution related activities.

(o) No specific public sector benefits from the project have been estimated.

(2) Marketing Division

(a) Additional criteria used in the selecting location are locations of the points of origin and amounts of intermodal and truck traffic moving out of the Richmond area and using the Norfolk Southern's Chesapeake facility.

(b) The demand at the start of operations has been determined by the marketing division using the drayage costs to the case study facility as against using the facility at Chesapeake. It was estimated to vary between 15,000 and 25,000 containers or trailer lifts per year. This did not include any new truck-to-rail diversions.

(c) The split between international to domestic shipments is assumed to start as high as 80:20, and as time goes by domestic truckload volumes are expected to increase, reaching even a 50:50 split.

(d) The breakdown on type of customers is assumed to follow the Norfolk Southern's overall intermodal business pattern, which is 50% steamship lines, 15% IMCs, and the rest truckload and premium type customers.

(e) Shippers' choice on terminals is understood to be based on combination of three key factors, namely, quality of rail service (i.e. whether it is free moving or congested over the line haul and at the terminal), closeness to shipper's warehouse or distribution center, and rate of transportation service. Customer support is also considered an important aspect of the service, such as responsiveness in providing rates and help.

(f) Performance measurement is done by the rail company by matching achieved against planned train schedules (i.e. at location of departure, points along the way and location of arrival).

(g) Marketing strategies used by the Norfolk Southern to attract customers include use of the IMCs, contracts with trucking companies, use of advertising campaign focusing on environmental benefits of intermodal transport, and sometimes calling up shippers directly to describe the facilities, capital projects and efforts being made by the rail company.

(h) Speaking on the pricing structure of intermodal service, the rate is determined on a point-to-point basis; it depends on type of international market (i.e. Atlantic or Trans Pacific traffic), terms of contract, etc. The rate for transporting empty containers is about 60% the rate for loaded containers. The customer is not offered different prices for use of single- and double- stack service. The arrangement of containers or trailers in single- and double- stacks and the routes are internally managed by the rail company. However, due to expansion of doublestack service, the cost of intermodal service is expected to fall once the Heartland Corridor project is completed. Drayage is priced on dollars per mile basis, which is equivalent to pricing it on a per move basis. Waiting times and delays at the terminal, due to the traffic, and at the customer’s warehouse are not paid for.

(i) It is customer’s responsibility to achieve balance in trade and to reduce empty movements.

(j) Premium and less than truckload (LTL) customers are provided separate truck lanes and faster train services, with 25-50% markup on the rate.

4.2.3 Prince George County Planning Department

As mentioned earlier, the local government of the Prince George County will play key role in establishment of the proposed terminal by funding access road improvements and performing rezoning activities.

(1) The Planning Department indicated that 1100 ft of the access road to the case study terminal is undergoing relocation and construction. The intersection of this

road with US-460 is also being shifted by 1000 ft along with geometric improvements. Contract for the road improvement works is currently being sent out for advertisement.

(2) Electricity can be readily provided to the proposed facility and associated infrastructure such as warehouses and distribution centers. However, water and sewer works will be taken up as and when developments establish.

(3) The Planning Department expects the terminal project to be taken up in 2008-2009.

(4) One positive aspect on the proposed location of the terminal identified was its proximity to an industrial park, an 1100-acre facility, of which a large portion is not developed. Currently, it holds only a few warehouses, distribution centers, and a metal works (manufacturer) facility. This indicates potential for growth and expansion of business for the intermodal terminal.

(5) Reflecting on the freight concerns raised by the Prince George County (Refer to **4.2.1**), it was found that the issue with US-460 improvements is that the current alignment makes it more difficult to move in and out of the industrial park, therefore an alternate alignment is proposed by the Planning Department that provides more direct access to US-460. Although this issue is not directly related to the case study facility, it can indirectly influence the intermodal business.

(6) Some of the other pertinent questions that received negative responses include absence of economic analysis for the case study project, lack of a database of the shippers or shipper surveys, and lack of information on IMCs in the region.

4.2.4 Consultations with the VDRPT and VDOT

During the course of the study, consultations were made with the VDRPT and VDOT freight planning divisions with regards to role played by the agencies in the planning of intermodal terminals. The VDRPT's project evaluation process as already described in **2.5.2** and **Table 4** were discussed and reaffirmed. It was realized that although the Norfolk Southern originally applied for public funding for the case study terminal at Petersburg, VA, public funds will not be availed. The only intermodal terminal project in the State that might receive public funding is the one proposed by the Norfolk Southern at Roanoke.

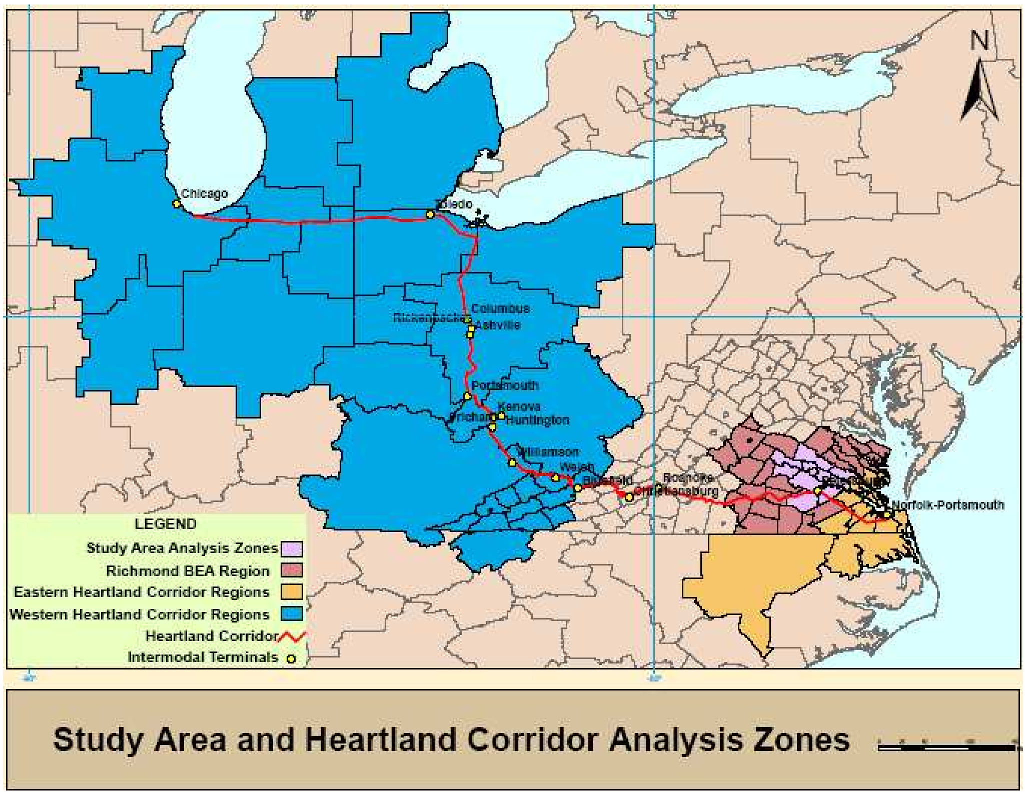
The VDOT, on the other hand, provided the Global Insight, Inc.'s TRANSEARCH database and other databases needed for the research. Clarifications on the form and usage of such data also have been provided by the VDOT.

4.3 Case Study Evaluation

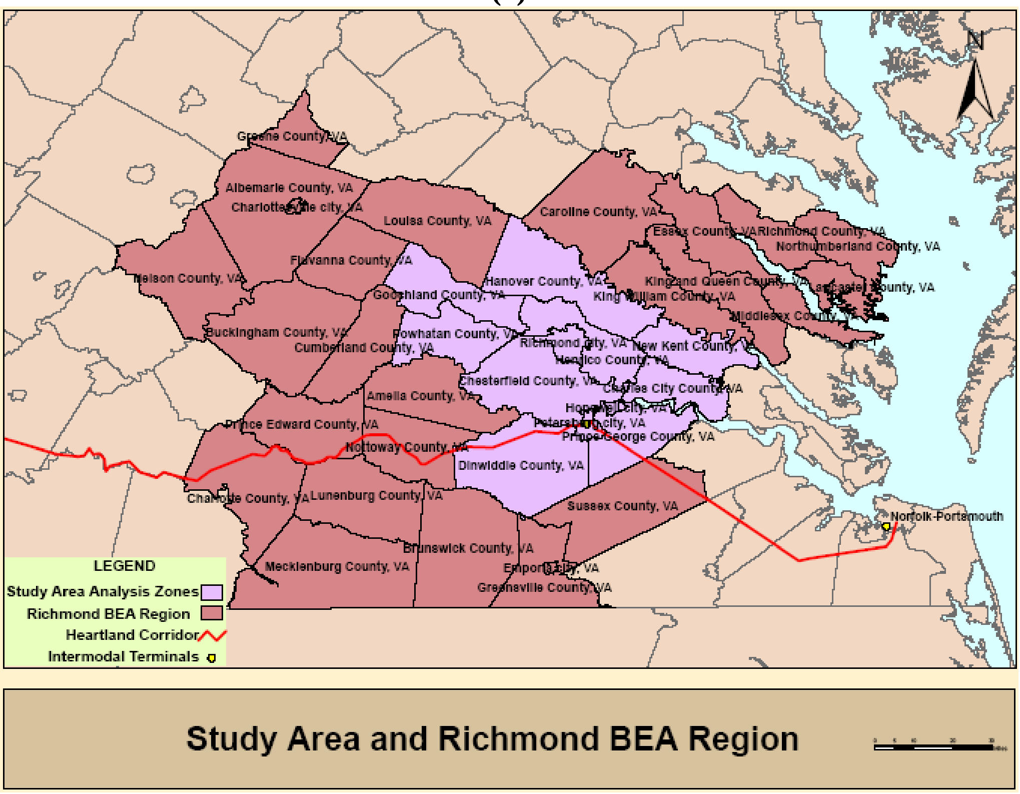
4.3.1 System Identification and Inventory

Evaluation of this step was conducted using findings of the interviews with the Norfolk Southern Corporation which is the main proponent of the case study terminal project. Although these results have already been presented, they are arranged so as to reflect the framework for evaluation:

(1) The purpose of the case study terminal is two-fold. Firstly, it is expected to relieve congestion at the Norfolk Southern's Chesapeake facility. Secondly, it will attract new intermodal business in the Richmond-Petersburg Metropolitan Statistical area for traffic moving along the Heartland Corridor (Refer to **Figure 13**).



(a)



(b)

Figure 13. Study Area Analysis Zones

(2) The case study terminal will be located in a Greenfield site close to a major four-lane highway (US-460) and also close to an industrial park which for most part is available for development. The land for developing warehouses and distribution centers is already available under the ownership of the Norfolk Southern Corporation. All developments will have electricity, water and sewer services at small marginal investment.

(3) The proposed terminal can substitute for the intermodal transportation needs of the Richmond-Petersburg MSA that are currently being served by the terminals at Norfolk and Portsmouth by the Norfolk Southern and CSX terminals. The drayage analysis region contains the Richmond-Petersburg MSA and locations of the competing facilities (Refer to **Table 7**). The size of analysis zones is limited to that defined in the commodity flow databases.

Table 7. Analysis zones considered for drayage analysis

Description	Name of the analysis zone
Richmond-Petersburg MSA	Charles City County
	Chesterfield County
	Colonial Heights City
	Dinwiddie County
	Goochland County
	Hanover County
	Henrico County
	Hopewell City
	New Kent County
	Petersburg City
	Powhatan County
	Prince George County
	Richmond City
Competing Facilities	Norfolk City
	Portsmouth City
	Alexandria City
	Warren County (Front Royal)

For the truck-to-rail diversion analysis, in addition to the counties in the Richmond-Petersburg MSA, other counties within the Richmond Bureau of Economic Analysis (BEA) Region and regions with centroids within a reasonable drayage distance (less than 200 miles) to the existing intermodal terminals along the Heartland Corridor (Refer to **Table 8**) are considered as the analysis zones.

Lastly, the impacts on the local warehouse movements are estimated for Counties within the Richmond BEA Region.

Table 8. Analysis zones considered for truck-to-rail diversion analysis

Description	Name of the location
Richmond-Petersburg MSA	Same as those listed in **Table 7**
Other Richmond BEA Region Counties	Albemarle County, VA
	Amelia County, VA
	Brunswick County, VA
	Buckingham County, VA
	Caroline County, VA
	Charlotte County, VA
	Cumberland County, VA
	Essex County, VA
	Fluvanna County, VA
	Greene County, VA
	Greensville County, VA
	King and Queen County, VA
	King William County, VA
	Lancaster County, VA
	Louisa County, VA
	Lunenburg County, VA
	Mecklenburg County, VA
	Middlesex County, VA
	Nelson County, VA
	Northumberland County, VA
	Nottoway County, VA
	Prince Edward County, VA
	Richmond County, VA
	Sussex County, VA
	Charlottesville City, VA
	Emporia City, VA

Description	Name of the location
Intermodal terminal locations along Heartland Corridor near which diversion analysis zones are considered	Norfolk, VA Petersburg, VA Bluefield, WV Welch, WV Williamson, WV Prichard, WV Kenova, WV Huntington, WV Portsmouth, OH Ashville, OH Rickenbacker ANGB Airport, OH Columbus, OH Toledo, OH Chicago, IL

(4) Based on earlier studies conducted at the Center for Transportation Studies and Global Insight, Inc.'s 2004 commodity flow data for the region, the key commodities were identified under the STCC categories as shown in **Table 9** [46]. Other movements that are considered in this Study include warehouse and distribution center and rail intermodal drayage. The STCC codes used for these movements in the Global Insight, Inc.'s TRANSEARCH database are 50 1 and 50 2, respectively. For the case of truck-to-rail diversion analysis, the STCC Codes of 11, 14 and 29 have been avoided as these are mostly transported by rail and are not subject to choice-making process. Due to sparseness of rail based ton data from 2005 Rail Waybill Sample, additionally STCC Code 21 has been avoided in analysis and the study BEA region (Richmond) has been combined with Virginia Beach-Norfolk-Newport News BEA Region and Raleigh-Durham-Cary BEA Region. The combined study area is referred to as the Eastern Heartland Corridor analysis zone. Corresponding to this, the tons of freight using truck mode have been aggregated over counties for the origin-destination BEA Regions.

Table 9. List of Key Commodities

2-Digit STCC Code	Description
11	Coal
14	Non-Metallic Minerals
20	Food or Kindred Products
21	Tobacco Products
23	Apparel or Related Products
24	Lumber or Wood Products
26	Pulp, Paper or Allied Products
27	Printed Matter
28	Chemical/Allied Products
29	Petroleum or Coal Products
30	Rubber or Miscellaneous Plastics
32	Clay, Concrete, Glass or Stone
35	Machinery
36	Electrical Equipment
37	Transportation Equipment

(5) The existing truck drayage movements between the analysis zones of the study area and the competing intermodal facilities are indicated in **Table 10**. The table also shows the estimated travel times in minutes (Refer to **3.2.2**). The existing truck and rail freight tons for Heartland Corridor origin/destination BEA Regions is tabulated in **Table 11**. The table also shows estimated shortest distance in miles for truck and rail modes between the centroids of analysis zones. For this purpose the “google” based mapping tool was used due to absence of traffic related data over the entire Heartland Corridor.

Finally, the existing truck freight movements between warehouse and distribution center truck freight movements within the Richmond BEA Region are presented in **Table 12**. The data collection and modeling included 95 counties and 41 cities within the Commonwealth of Virginia.

Table 10. Existing truck drayage totals (STCC Code 50 2) between the study area analysis zones and the competing facilities

FIPS Code	Origin/ Destination County or City	Portsmouth/ Norfolk Terminal		Alexandria Terminal		Front Royal Terminal	
		Annual Tons	Estimated Travel Time (in minutes)	Annual Tons	Estimated Travel Time (in minutes)	Annual Tons	Estimated Travel Time (in minutes)
51036	Charles City County	2	115	60	266	0	222
51041	Chesterfield County	36,284	146	629	249	1,003	175
51570	Colonial Heights City	2,909	131	33	264	48	208
51053	Dinwiddie County	41,416	119	491	317	287	262
51075	Goochland County	117	196	0	249	82	125
51085	Hanover County	29,487	196	1,192	172	510	163
51087	Henrico Cunty	58,047	148	2,047	229	865	184
51670	Hopewell City	23,518	120	295	259	430	203
51127	New Kent County	431	137	0	247	0	203
51730	Petersburg City	6,232	130	67	275	66	220
51145	Powhatan County	327	178	0	259	0	143
51149	Prince George County	2,752	110	28	266	25	211
51760	Richmond City	31,783	169	399	233	581	177

Table 11. Truck-Rail distribution of freight tons along Heartland Corridor

FIPS Code	Origin/ Destination BEA Region	Truck Flows to/from Eastern Heartland Corridor Analysis Zone		Rail Flows to/from Eastern Heartland Corridor Analysis Zone	
		Annual Tons	Distance in miles*	Annual Tons	Distance in miles*
45	Rest of Johnson City	1,462,732	317	6,880	586
47	Rest of Lexington	412,562	440	0	684
48	Charleston, WV	991,590	352	3,216	703
49	Cincinnati, OH	714,472	526	34,480	780
50	Dayton, OH	163,536	563	0	863
51	Columbus, OH	482,214	480	10,840	808
55	Cleveland, OH	1,638,397	520	37,560	1,062
56	Toledo, OH	417,179	609	11,320	984
57	Detroit, MI	800,556	655	349,177	1,035
62	Grand Rapids, MI	166,701	688	0	1,001

FIPS Code	Origin/ Destination BEA Region	Truck Flows to/from Eastern Heartland Corridor Analysis Zone		Rail Flows to/from Eastern Heartland Corridor Analysis Zone	
		Annual Tons	Distance in miles*	Annual Tons	Distance in miles*
63	Milwaukee, WI	381,806	743	7,720	1,065
64	Chicago, IL	1,689,577	725	238,216	1,296
65	Elkhart, IN	225,985	703	2,120	1,329
66	Fort Wayne, IN	114,199	834	0	1,214
67	Indianapolis, IN	855,786	947	71,360	1,302
68	Champaign, IL	156,238	764	36,000	1,362

Note *Distance measurements made using “google” mapping tools and coordinates

Table 12. Area-wise warehouse and distribution center (STCC Code 50 1) truck freight movements within Richmond BEA Region

FIPS Code	Region	Warehouse and Distribution Center Annual Truck Tons
51003	Albemarle County, VA	171,239
51007	Amelia County, VA	75,644
51025	Brunswick County, VA	489,299
51029	Buckingham County, VA	437,569
51033	Caroline County, VA	193,955
51036	Charles City County, VA	37,654
51037	Charlotte County, VA	116,213
51041	Chesterfield County, VA	3,779,364
51049	Cumberland County, VA	16,537
51053	Dinwiddie County, VA	525,987
51057	Essex County, VA	107,410
51065	Fluvanna County, VA	38,409
51075	Goochland County, VA	29,838
51079	Greene County, VA	15,769
51081	Greensville County, VA	45,489
51085	Hanover County, VA	1,740,372
51087	Henrico County, VA	3,287,882
51097	King and Queen County, VA	92,645
51101	King William County, VA	285,332
51103	Lancaster County, VA	72,406
51109	Louisa County, VA	679,551
51111	Lunenburg County, VA	112,184
51117	Mecklenburg County, VA	474,812
51119	Middlesex County, VA	41,401
51125	Nelson County, VA	102,047
51127	New Kent County, VA	13,039
51133	Northumberland County, VA	92,627
51135	Nottoway County, VA	149,572
51145	Powhatan County, VA	13,178

FIPS Code	Region	Warehouse and Distribution Center Annual Truck Tons
51147	Prince Edward County, VA	33,716
51149	Prince George County, VA	810,385
51159	Richmond County, VA	85,606
51183	Sussex County, VA	285,654
51540	Charlottesville city, VA	109,044
51570	Colonial Heights city, VA	79,820
51595	Emporia city, VA	131,971
51670	Hopewell city, VA	2,438,708
51730	Petersburg city, VA	268,218
51760	Richmond city, VA	1,230,296

(6) Few of the demographic and economic data for analysis zones within the Commonwealth of Virginia were collected from the 2006 Census Bureau's quick facts as follows: (a) population, (b) per capita income and (c) area. Analysis zone wise transportation related employment data was obtained from the database available for an earlier study at the Center for Transportation Studies belonging to the year 1999. The data is presented in **Table B1** in **Appendix B** to this thesis.

To develop the safety impact models on the study area highway network, link-wise truck involved crash data, length, and AADT data were collected for three consecutive years from 2003 to 2005 for the Commonwealth of Virginia under different functional classes of highways, namely, rural and urban interstates and rural and urban non-interstates. Only categories up to the level of major collectors are considered in the analysis. Non-intersection type crashes are selected by avoiding crashes within 150 ft of an offset from the nodes.

4.3.2 Obtaining shipper requirements and preferences

Due to shortage in time and resources this step of the framework for evaluation has not been carried out. Instead it is suggested that future research be conducted to identify suitable instruments to conduct stated preference surveys. Also, the ways to use the stated preference data to establish utility functions corresponding to individual attributes and the ways to combine these utility components to form a single utility function need to be investigated. Finally, the benefit of conducting such a study for an intermodal project evaluation needs to be assessed.

4.3.3 Estimating demand and drayage

Based on the interviews it was realized that no long-term shipping agreements have been signed so far for the case study terminal. Hence, there is no captive demand that can be assigned to the proposed terminal. The market analysis performed by the Norfolk Southern Corporation was focused on diversion of traffic from their current terminal at Chesapeake, VA. As this analysis results were not available, demand estimation is performed for the case study facility as described in the methodology.

(1) Diversions from existing intermodal facilities

(a) Besides the values in **Table 10**, the travel times from the analysis zones to the proposed terminal are estimated as shown in **Table 13**.

Table 13. Estimated travel time to proposed terminal near Petersburg, VA

FIPS Code	Origin/ Destination County or City	Estimated Travel Time to Petersburg Terminal (in minutes)
51036	Charles City County	34
51041	Chesterfield County	45
51570	Colonial Heights City	31
51053	Dinwiddie County	44
51075	Goochland County	95
51085	Hanover County	105
51087	Henrico County	48
51670	Hopewell City	20
51127	New Kent County	65
51730	Petersburg City	26
51145	Powhatan County	77
51149	Prince George County	21
51760	Richmond City	68

(b) In the first stage of the accessibility model (Refer to **3.2.3**), a multinomial logit model is fitted between the choice of the terminal and scaled travel time deviation with tons of freight to the chosen terminal acting as weights for estimation using CATMOD procedure in SAS. On inspection of data, Charles City County is identified as an outlier and hence not considered in model estimation. Parameters for **Equations (1)** are estimated as shown in **Table 14**. The SAS code and data input file for this stage of the model has been attached as **Appendix C**.

Table 14. Parameter estimates for multinomial logit model

Variable	Description	Parameter Estimates	Std Error	t Value	Pr > |t|
Intercept	Equation (1a)	3.4972	0.0164	45420.51	<.0001
	Equation (1b)	-2.0599	0.0562	1345.41	<.0001
Scaled Travel	Equation (1a)	-5.3408	0.0936	3257.48	<.0001
Time Deviation	Equation (1b)	18.3688	0.3239	3215.44	<.0001

The model fit is found to be good with respect to the freight ton splits to the existing terminals (indicated by the high absolute t values). By pooling the first stage model results of logistic function estimates from the two parts of **Equations (1)**, a pooled ordinary linear regression model as given by **Equation (2)** is estimated. The results of the regression are shown in **Table 15**.

Table 15. Parameter estimates for linear regression model between ratio of choice probabilities and scaled travel time deviation

Variable	Description	Parameter Estimates	Std Error	t Value	Pr > |t|
Intercept	Equation (3)	6.04468	0.23266	25.98	<.0001
Scaled Travel Time Deviation	Equation (3)	-4.56243	0.42146	-10.83	<.0001

The model fit results are as follows:

$R^2 = 0.87$ and $Adjusted \quad R^2 = 0.86$

Using this two stage accessibility model, in probabilistic terms the analysis zone wise drayage splits in the existing and proposed conditions are predicted as shown in **Table 16**. The overall predicted market shares of the terminals in existing and proposed conditions are indicated in **Figure 14**.

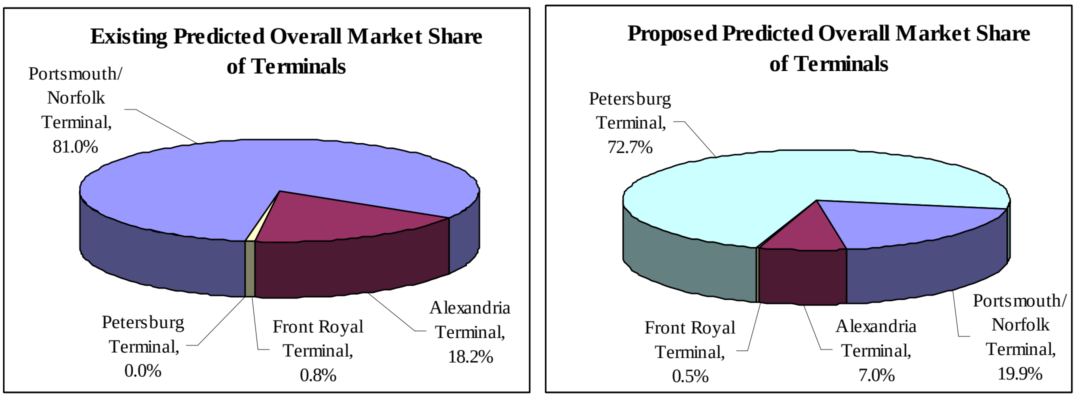


Figure 14. Overall Market Shares of Intermodal Terminals in Existing and Proposed Conditions

(2) Diversions from truck-to-rail

(a) As discussed earlier, the terminals closer to the proposed terminals have been grouped into a single analysis zone, namely, the Eastern Heartland Corridor analysis zone.

(b) The analysis zones away from the study area satisfying the model requirements can be identified from the **Table 11**. Hence, the data corresponding to Rest of Johnson City, Rest of Lexington, Charleston, WV and Columbus, OH is avoided in the estimation of the mode choice model.

Table 16. Actual and predicted drayage split probabilities for existing and proposed conditions

FIPS Code	County/ City	Existing Actual				Existing Predicted				Proposed Predicted			
		Portsmouth/ Norfolk Terminal	Alexandria Terminal	Front Royal Terminal	Petersburg Terminal	Portsmouth/ Norfolk Terminal	Alexandria Terminal	Front Royal Terminal	Petersburg Terminal	Portsmouth/ Norfolk Terminal	Alexandria Terminal	Front Royal Terminal	Petersburg Terminal
51036	Charles City	0.03	0.97	0.00	0.00	0.93	0.07	0.00	0.00	0.24	0.03	0.00	0.73
51041	Chesterfield	0.96	0.02	0.03	0.00	0.90	0.10	0.01	0.00	0.18	0.04	0.00	0.78
51570	Colonial Heights City	0.97	0.01	0.02	0.00	0.92	0.08	0.00	0.00	0.19	0.03	0.00	0.77
51053	Dinwiddie	0.98	0.01	0.01	0.00	0.94	0.05	0.00	0.00	0.28	0.02	0.00	0.70
51075	Goochland	0.59	0.00	0.41	0.00	0.70	0.25	0.05	0.00	0.17	0.08	0.02	0.73
51085	Hanover	0.95	0.04	0.02	0.00	0.36	0.62	0.01	0.00	0.17	0.23	0.01	0.59
51087	Henrico	0.95	0.03	0.01	0.00	0.83	0.16	0.01	0.00	0.18	0.06	0.00	0.75
51670	Hopewell City	0.97	0.01	0.02	0.00	0.93	0.07	0.00	0.00	0.18	0.03	0.00	0.79
51127	New Kent	1.00	0.00	0.00	0.00	0.88	0.11	0.00	0.00	0.25	0.06	0.00	0.69
51730	Petersburg City	0.98	0.01	0.01	0.00	0.92	0.07	0.00	0.00	0.19	0.03	0.00	0.78
51145	Powhatan	1.00	0.00	0.00	0.00	0.82	0.14	0.03	0.00	0.18	0.05	0.01	0.76
51149	Prince George	0.98	0.01	0.01	0.00	0.94	0.06	0.00	0.00	0.21	0.02	0.00	0.77
51760	Richmond City	0.97	0.01	0.02	0.00	0.79	0.20	0.01	0.00	0.19	0.08	0.01	0.73

(c) Corresponding to the pair of analysis zones in (a) and (b), the tons of freight excluding the mode specific commodity types have been presented in **Table 11**.

(d) The distance attribute information is also gathered for selected pairs of analysis zones over rail and truck modes as shown in **Table 11**.

Based on the data collected, it was found that in addition to distance, few of the origin/destination locations exhibited high freight flows by rail relative to truck flows. Chicago, IL, Detroit, MI, and Champaign, IL are such exceptions. It was realized that these set of origin/destination locations introduce region specificity. In case of Chicago BEA Region, its intermodal hub character and connectivity to the west coast through forwarding rail lines are the reasons. In case of Detroit and Champaign BEA Regions, the regions act as unique suppliers of specific commodity types, namely transportation equipment and food and kindred products, respectively. To overcome this problem an indicator variable was introduced in the model which takes the value of one for the aforementioned locations and zero otherwise, thereby stratifying the data into two groups. The modified model is written as follows:

$$\ln\left(\frac{TruckTonFlow}{RailTonFlow}\right) = Intercept + \beta_1\left(DiffDist\right) + \beta_2\,(RegionSpecIndic) \quad \textbf{(5)}$$

The SAS code and data input file for this model has been attached as **Appendix C**. Modeling results have been indicated in **Table 17** below:

Table 17. Parameter estimates for linear regression model between ratio of truck to rail ton flows and difference in mode wise distance estimates

Variable	Description	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Equation (5)	2.38148	0.46013	5.18	0.0035
DistDiff	Equation (5)	0.00334	0.00102	3.28	0.0219
RegSpecIndic	Equation (5)	-2.68689	0.27873	-9.64	0.0002

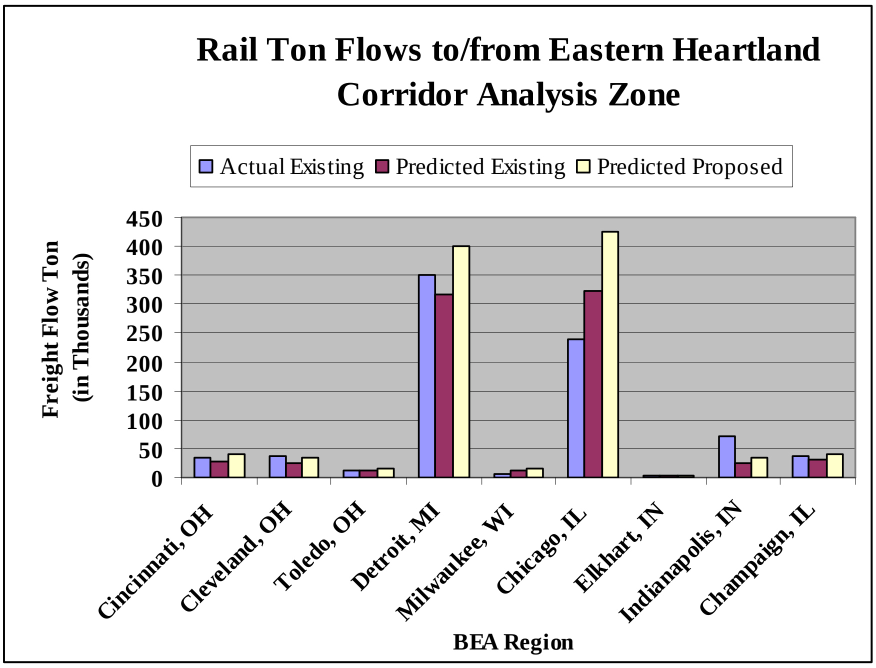
The results of the fit are as follows:

$$R^2 = 0.95, \; Adjusted \quad R^2 = 0.93$$

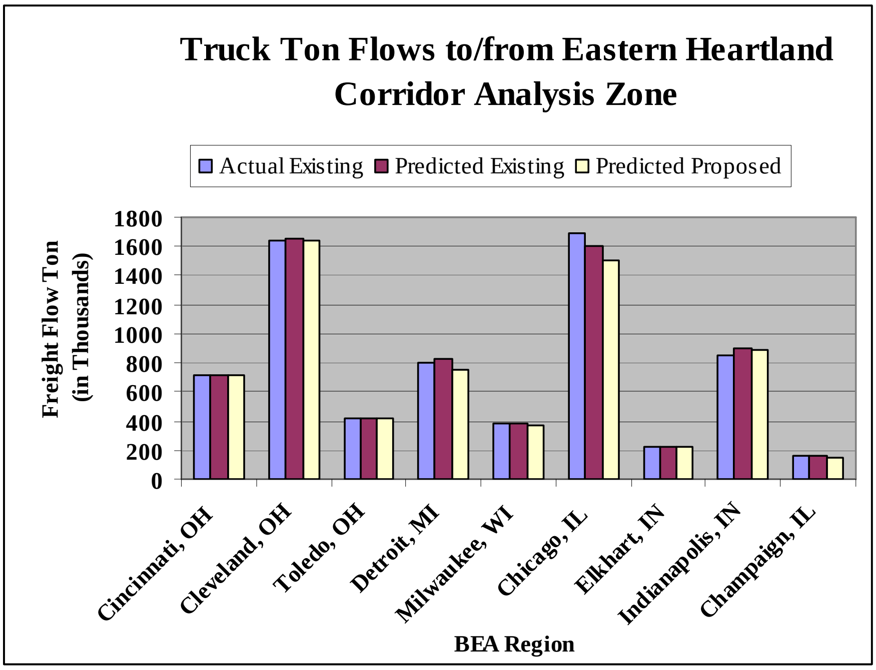
Using this model, the actual and predicted truck and rail ton flows in the existing and proposed conditions are shown in **Figure 15**.

(3) Future demand and drayage

Although truck forecasts were available from TRANSEARCH database, due to lack of rail forecasts and time constraints on the Study, this step has not been taken up. However, the methodology proposed is similar to that described in previous two steps.



(a)



(b)

Figure 15. Actual and predicted rail and truck flow annual tons to Eastern Heartland Corridor analysis zone

4.3.4 Selecting and evaluating MOEs (QMs and PMs)

The results of the evaluation of selected MOEs as per the methodology are as follows:

(1) Safety

Truck routes were identified using the Oak Ridge National Laboratory's highway network provided along with the TRANSEARCH database. However, information regarding truck restrictions was not collected for planning level analysis over multiple BEA regions. It was assumed that the identified road network imposes no truck restrictions.

Safety analysis models for truck involved non-intersection type crashes are built for highways of different functional classification using the crash database on highways in the Commonwealth of Virginia. The results of the fitted models (Refer to **3.2.4**) are indicated in **Table 18**.

Using these models, the Study showed that there will be reduction by **6 PDO type crash equivalents** on the study area road network annually. Thus, the impact of the proposed terminal on the study area is not significant in terms of safety.

In addition, over the interview it was noted that the terminal location was selected far away from at-grade rail crossings, thus reducing risk of related crashes.

(2) Mobility

Mobility impact in the Study is measured for the two modes in terms of only change in ton miles. The terminal will result in a reduction of **116,347,841 ton miles** for the truck mode and an increase of **201,312,804 ton miles** for the rail mode.

(3) Accessibility

The change in accessibility is measured in terms of travel time saved/lost for freight traffic in the study area using the competing intermodal terminals. This is based on change in the estimated number of drayage trucks and travel times on links of the study area analysis zones under existing and future conditions of traffic. The value of time savings for drayage traffic in the study area due to introduction of a new intermodal terminal is estimated to be about **10,166 truck-hours** annually.

Table 18. Parameter estimates for Negative Binomial model between number of truck involved crashes and standardized AADT and standardized length

Parameter	Description	Interstate Rural	Interstate Urban	Non-Interstate Rural	Non-Interstate Urban
Intercept	**Estimate**	-2.5306	-1.6845	-1.9249	-2.8812
	Std Error	0.2503	0.144	0.0892	0.131
	Chi-sq	102.2	136.85	465.14	483.67
	Pearson's chi-sq statistic	<.0001	<.0001	<.0001	<.0001
AADT	**Minimum (PCU)**	4,169	5,139	65	157
	Maximum (PCU)	47,929	127,596	47,194	103,284
Standardized AADT	**Estimate**	1.5149	2.7932	2.3444	4.1278
	Std Error	0.4831	0.2716	0.274	0.3992
	Chi-sq	9.84	105.79	73.2	106.94
	Pearson's chi-sq statistic	0.0017	<.0001	<.0001	<.0001
Length	**Minimum (miles)**	0.02	0.02	0.01	0.01
	Maximum (miles)	9.39	7.38	19.14	12.94
Standardized Length	**Estimate**	2.5213	2.719	5.5907	11.692
	Std Error	0.3802	0.344	0.311	0.8298
	Chi-sq	43.97	62.48	323.07	198.53
	Pearson's chi-sq statistic	<.0001	<.0001	<.0001	<.0001
Dispersion	**Estimate**	0.4345	0.5412	1.3383	2.9353
	Std Error	0.2009	0.1001	0.1055	0.249
	Comment	Underdispersed	Underdispersed	Overdispersed	Overdispersed

Due to absence of information on locations of major activity centers, residences, work places, manufacturers, retailers, warehouses and distributions centers within the study area, impact of the case study terminal on their connectivity or inter-accessibility has not been studied. However, if more information were made available, corresponding changes in travel time could be estimated.

(4) Land Use and Secondary Local Passenger Traffic

Due to time constraints on the Study, no specific land use model was tested out to determine the impact of the case study project on land use and the resulting secondary local passenger traffic. Considering the availability of additional land under the ownership of the rail company for encouraging support infrastructure, intensification of land use may not be a major concern to the rail company in the near future.

(5) Economic Development and Secondary Local Freight Traffic

Like in land use impacts, no specific input-output model could be tested out due to time constraints on the Study. However, the model for the secondary local freight traffic was estimated, i.e. relationship between the demographic and economic variables and warehouse and distribution center truck flows was established.

The variables freight flows, population and transportation related employment were normalized by dividing them by area of the analysis zone and taking log transformation, as found necessary. The transformation was decided based on univariate properties of the variables, their normality and box-plots thereto. Also, inspection of pair-wise scatter diagrams was conducted between the dependent variable, namely, the warehouse flows and the explanatory variables. The model form that is finalized is as shown as follows:

$$\log\left(\frac{WareTrkTons}{Area}\right) = Intercept + \beta_1 \log(PopDens) + \beta_2 PCI + \beta_3 \log\left(\frac{TranEmp}{Area}\right) \quad \textbf{(6)}$$

Other than records with missing data (mainly employment), 5 out of 95 County records were eliminated as outliers (namely, Buchanan County, Craig County, Dickenson County, Highland County and Wise County**)**. The results of the model are shown in **Table 19** as follows:

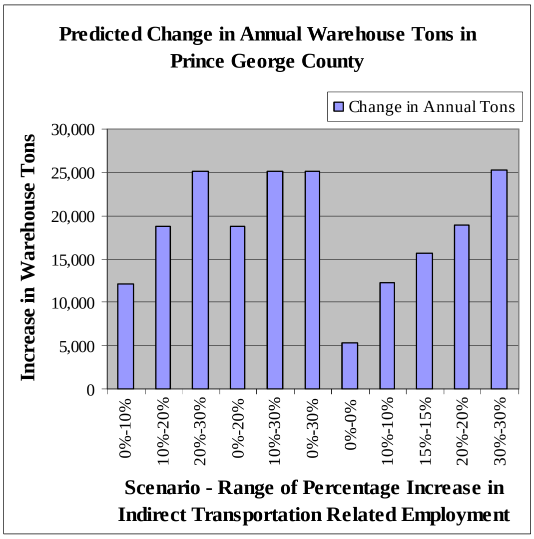
Table 19. Parameter estimates for linear regression model between logarithm of warehouse and distribution center truck tons and economic variables

Variable	Description	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	Equation (6)	24.8005	5.3144	4.67	<.0001
lnPopDens	Equation (6)	0.8153	0.1632	4.99	<.0001
lnPCI	Equation (6)	-2.2236	0.5488	-4.05	<.0001
lnNormTranEmp	Equation (6)	0.4288	0.1403	3.06	0.0028

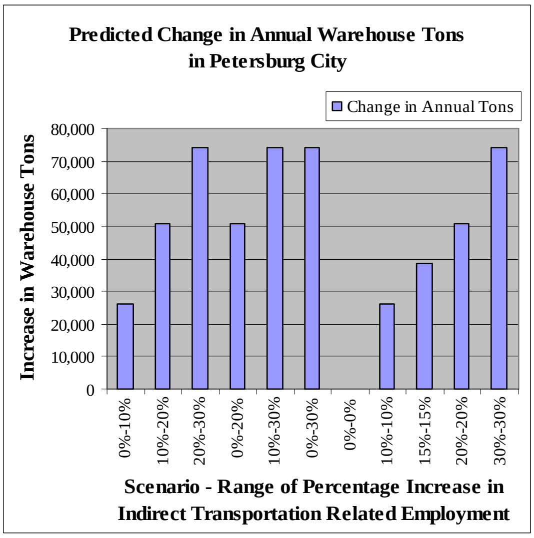
The results of the fit are as follows:

$R^2 = 0.79$, $Adjusted \quad R^2 = 0.78$

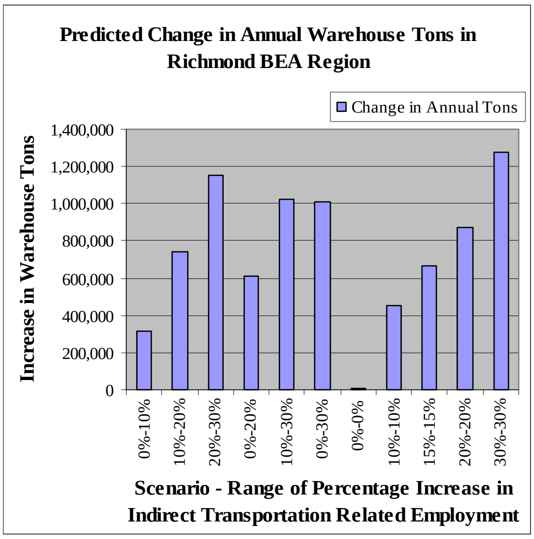
From the knowledge of direct and indirect transportation related employment opportunities created by an intermodal terminal the changes in warehouse and distribution center freight movements can be estimated. Based on the interviews, it was found that about 10 employees will directly be employed by the proposed intermodal terminal. Taking the effect of the direct employment, increase in annual warehouse and distribution center truck flow is estimated using the model as about **5314 tons**. In addition to this, in order to understand the model behavior, a sensitivity analysis has been performed superimposing the impact of indirect employment. The percentage increase in indirect employment is assumed to vary between a minimum and maximum percentage value and is determined by a linear function of the distance of the study area analysis zone from the proposed terminal. The results of the sensitivity analysis have been plotted in **Figure 16**.



(a)



(b)



(c)

Figure 16. Sensitivity analysis for the effect of increase in indirect employment on warehouse and distribution center truck flows

It can be observed from the plots that the marginal increase in annual tons by a shift in the range of sensitivity parameter is decreasing in all of the cases: (a) 0%-10% to 10%-20% to 20%-30%; (b) 0%-10% to 0%-20% to 0%-30%; and (c) 0%-0% to 10%-10% to 20%-20% to 30-30%.Higher the range of sensitivity parameter higher the change in warehouse and distribution center truck tons. For example, 0%-20% as compared to 10%-10%, 10%-30% as compared to 20%-20%, and 0%-30% as compared to 15%-15%. Further research needs to be carried out in estimating the impact of an intermodal terminal investment on the economic and demographic variables of the region where it is located.

(6) Profitability to Shippers

To incorporate the shipper's perspective, end user transportation costs and benefits were assessed for the proposed condition relative to the existing condition, including changes in drayage costs, truck to rail diversion cost savings, and new rail costs, calculated with respect to existing conditions. A summary of these costs as calculated for the study area and other Heartland Corridor analysis zones is shown in **Table 20**.

Table 20. Estimated overall transportation related costs and benefits

Sl No	Type of Impact	Annual Costs (in $)	Annual Benefits (in $)
1	New Dray Flow Impacts on Eastern Heartland Corridor	1,256,417	
2	Existing Dray Flow Impacts on Eastern Heartland Corridor		339,486
3	New Dray Flow Impacts on Western Heartland Corridor	842,466	
4	Increase in Rail Costs (Terminal-to-Terminal)	10,789,598	
6	Truck Diversion Impacts		12,847,508
	TOTAL	**12,888,481**	**13,186,993**

Costing assumptions made in the study include: (a) Drayage costs were priced at $1.10 per mile per truck as suggested by the rail company during the interview; (b) Diverted truck movements and warehouse truck movements were priced at $1.59 per truck-mile based on market values[↑]; (c) Intermodal rail transportation user charges for terminal-to-terminal movements from Norfolk to Chicago, IL and Norfolk to Columbus, OH were used to estimate costs for the study origin-destination pairs using distance based interpolation; (d) Empty movements were not considered in the cost analysis. Also, average loading factors for drayage, truck diversions and warehouse movements were estimated and used as 26.69 tons/truck load, 20.29 tons/truck load and 20.65 tons/tuck load, respectively.

The net monetary benefit of the terminal is estimated to be about **$298,500** and the benefit-to-cost ratio is about **1.02**.

(7) Changes in Environmental Setting

Based on the interview with the railroad company, the location of the terminal was selected in such a way that the environmental impacts are kept to a minimum. The land being already owned by the Norfolk Southern and the size of the facility being modest, there are no significant community impacts anticipated. The location of the terminal falls along a commercial corridor with heavy volumes of existing truck traffic on highways. The truck traffic generated by the terminal will have a small added impact. Detailed environmental impact analysis is beyond the scope of this Study.

[↑] http://www.truckloadrate.com/market_truck_rates.htm last assessed on October 21, 2007

(8) Preservation and Management

Considering the preservation and management of the study area road network the total truck miles saved is estimated. The results are shown in **Table 21** below:

Table 21. Estimated truck miles saved on study area road network

Sl No	Type of Impact	Annual Truck Miles Saved
1	New Dray Flow Impacts	-454,322
2	Existing Dray Flow Impacts	308,623
3	Truck Diversion Impacts	1,113,286
4	Warehouse and Distribution Center Flow Impacts	-65,218
	NET TOTAL	**902,369**

Considering a truck covers about 15,000 miles per year on an average, the above savings is equivalent to saying that about **6 trucks** are removed from the highways in a year. Thus, the savings due to the terminal on account of truck miles is not very high.

4.3.5 Combining different MOEs into a single score for ranking purposes

Due to requirements for further research with regards to the methodology for scoring and ranking intermodal freight projects within a MIN this step of the case study evaluation is not completed. However, by selecting a study area road network overlapping mainly with the Richmond to Hampton Roads Passenger and Goods Movement MIN, the intermodal terminal project impacts on this MIN are evaluated.

4.3.6 Storage, retrieval and updating of impact information

As a conclusion to the analysis, the different types of impacts were documented and GIS was used to store information, which at a later point of time can be retrieved or updated. **Figure 17** indicates the link wise impact information on the study analysis zones and the study area road network stored in ArcGIS format files.

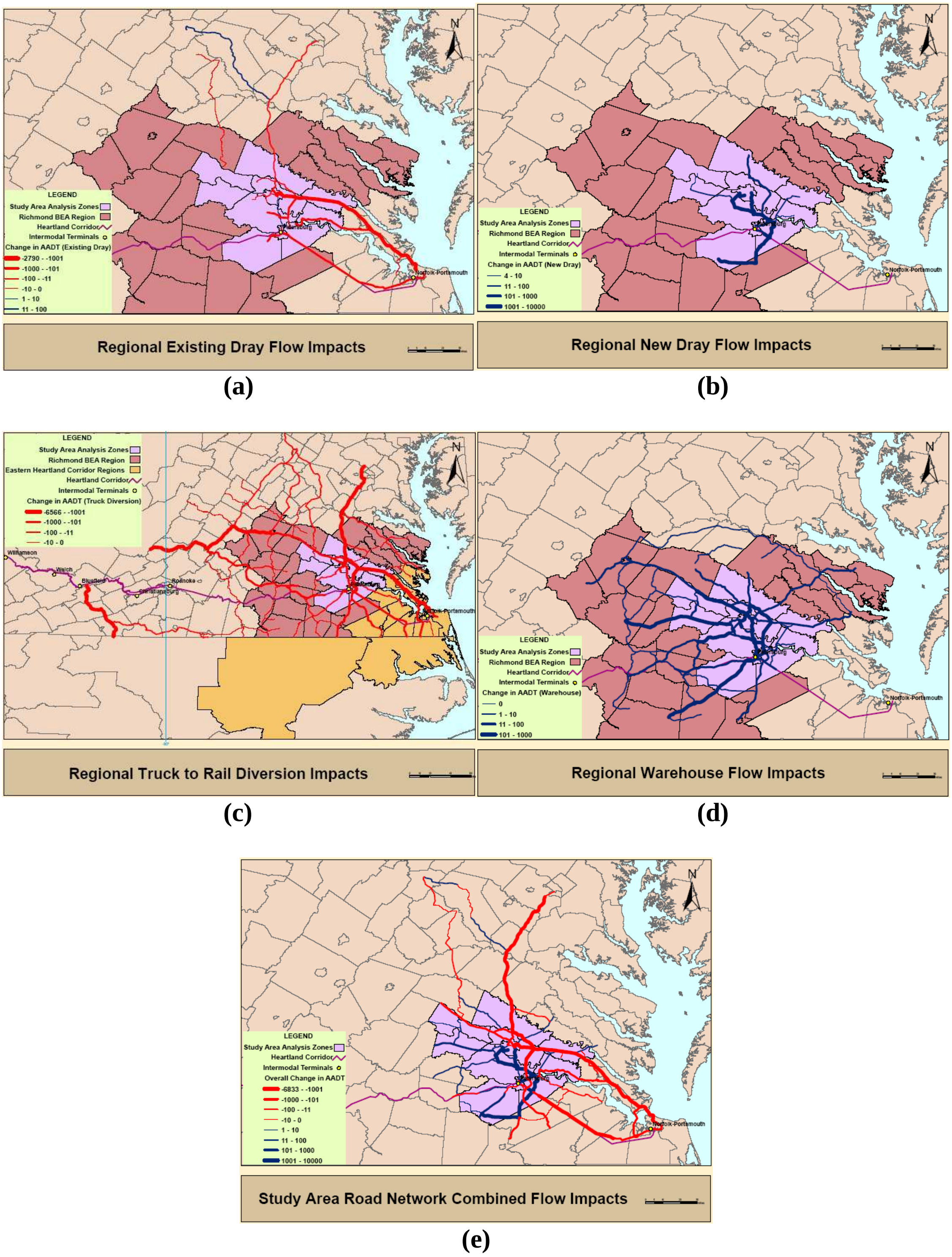


Figure 17. ArcGIS based Storage of Impact Information for Study Area

4.4 Summary of Case Study Evaluation Results

The results of modeling are summarized in

Table 22. It lists the measures used to assess fitness of the several models developed in the study.

Table 22. Summary of Model Results

Sl No	Model Description	Fitness Measure
1	Stage 1 Accessibility Model	High t-values for coefficients of explanatory variables
2	Stage 2 Accessibility Model	Adjusted $R^2 = 0.86$
3	Mode Choice Model	Adjusted $R^2 = 0.93$
4	Negative Binomial Crash Count (Safety) Models	High chi-sq values for coefficients of explanatory variables
5	Secondary Local (Warehouse) Freight Flow Impact Model	Adjusted $R^2 = 0.78$

On the other hand, **Table 23** provides a summary of the results obtained for case study evaluation under the different categories of qualitative and performance measures.

Table 23. Summary of Evaluated MOEs (QMs and PMs)

MOE type	QM	PM
Safety	• Selected terminal location is away from at-grade rail crossings. • Geometric improvements of access road will be carried out by the Prince George County.	• Reduction in crashes by 6 PDO type crash equivalents
Mobility	• Proposed terminal will provide transportation alternative to the Heartland Corridor freight traffic. • Physical characteristics of the terminal can allow a throughput of about 30,000 lifts/year.	• 116,347,841 ton miles reduction in truck flow • 201,312,804 ton miles increase in rail flow
Accessibility	• The proposed terminal location is close to US-460 and I-295 highway facilities. • Geometric improvements of access road will be carried out by the Prince George County.	• Annual savings of 10,166 drayage truck-hours in the study area using the competing intermodal terminals
Land Use	• The land acquisition cost for the proposed terminal site is not high. • An 1100-acre industrial park exists	• None evaluated

MOE type	QM	PM
Economic Development	close to the proposed terminal with very few current developments. • The terminal will provide direct employment to ten people and may result in construction of warehouse facilities in the vicinity. • IMCs will be used by the railroad company to sell the intermodal service. • Area south of Petersburg city is showing potential for growth in industries and use of intermodal freight transportation.	• Increase in warehouse flows by 5,314 tons annually in and out of Prince George County
Profitability to Shippers	• Doublestack operations will be made available at the proposed terminal • IMCs will be used by the railroad company to sell the intermodal service.	• Cost-benefit ratio = 1.02 • Net monetary benefit = $298,500
Environment	• Proposed terminal location is a Greenfield site and has minimal effect on wetlands	• Reduction in emissions corresponding to 902,369 truck miles saved annually within the study area
Preservation & Management	• The proposed terminal is expected to capture the freight traffic using Norfolk Southern's Chesapeake terminal, and thus likely to reduce the truck traffic along US-460 and I-64 between Richmond, VA and Norfolk, VA.	• 902,369 truck miles saved annually within the study area

CHAPTER 5: CONCLUSIONS, SIGNIFICANCE AND LIMITATIONS

5.1 General

In this chapter the conclusions, significance and limitations of the Study are presented. The data collection, analysis and processing techniques, and methodologies for qualitative and quantitative evaluation used in this Study are generalized to the extent possible in order to ensure their applicability to a wide range of intermodal terminal projects.

5.2 Conclusions

(1) Evaluation of an intermodal terminal project requires a systematic multi-regional modeling approach, and it is highly data intensive and interdisciplinary in nature.

(2) The impacts of an intermodal terminal are region and trade corridor specific because the accessibility to highway/rail, distance from competing terminals and the spatial distribution of intermodal freight demand varies from location to location.

(3) In cases such as the proposed terminal, where estimated intermodal rail drayage forms a small share of the overall truck traffic, the introduction of an intermodal terminal does not have substantial impacts on accessibility, mobility or safety on the truck routes, to the extent that these factors were evaluated in the Study.

(4) Upon completion of the case study terminal, there is expected to be noticeable reduction of truck traffic on I-64 and a slightly lesser reduction of truck traffic on

US-460. Both of these highways form connecting links to the competing terminals.

5.3 Significance

(1) The Study provided a comprehensive framework for evaluation of intermodal terminal projects. As the framework is derived from the State goals and objectives, it makes it feasible to compare with other freight projects in terms of level of fulfillment of goals and objectives.

(2) The Study developed several models for estimation of impacts, including a two-stage accessibility model for drayage shift from competing terminals, a truck-rail mode choice model, truck involved crash models for interstate/non-interstate urban/rural combinations, and secondary local freight traffic impact model have been developed in this Study. All of these models were estimated using data from the Commonwealth of Virginia.

(3) Several challenging problems in evaluating an intermodal terminal were identified such as use of simulation techniques for the evaluation, measurement of service attributes, collection and use of stated preference surveys, estimation of empty flows, determine ways to link intermodal investment with land use pattern and in turn changes in passenger trips and determine ways to link intermodal investment with economic and demographic variables.

(4) Storage of impact information is a useful component of the framework which allows retrieval, updating and comparison of data at a later point of time.

(5) The case study evaluation helped clarify the structured approach described by the framework for evaluation.

5.4 Limitations

(1) Full scale evaluation of the MOEs for the case study intermodal terminal could not be carried out. In cases, where evaluation was not carried out future research and data requirements have been indicated.

(2) Different commodity flow data sources use different sampling rates and different techniques to estimate Origin-Destination flows as explained in Chapter 2. Unfortunately, this problem cannot be overcome unless the same data source provides all information needed for the evaluation.

(3) Terminal characteristics other than accessibility have not been considered in determining drayage split between competing terminals. Hence, the effect of size of the terminal and type of the terminal infrastructure used (equipment, storage facility, warehousing, etc.) on terminal choice could not be studied.

(4) The Study used cross-sectional data belonging to a single time period. Demand and drayage predictions were made for the scenario immediately after the start of terminal operations.

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APPENDIX A: Sample Questionnaire to Intermodal Terminal Managers

<u>Planning for Successful Intermodal Terminals in Virginia - Summary of Questions</u>

Contact Details for _____________ Terminal
[Name, Title]
[Address]
[Phone, Fax]
[Email]

1. *History of the terminal*
   a) When was the intermodal terminal established?
   b) How was it originally funded?
   c) What factors influenced its original location?
   d) What were the private and public roles in establishing the terminal?

2. *Current operations*
   a) What work units (public and/or private) are involved in the operations of the terminal?
   b) Is the terminal exclusively used for COFC/TOFC freight?
   c) Is the intermodal traffic domestic, international, or both?
   d) What is the extent of the market covered in terms of maximum drayage distance?
   e) What are the various services provided at the terminal?
   f) What are the major commodities handled by the terminal?

3. *Coordination with public and private stakeholders*
   a) What are the possible sources of funding for improvements?
   b) Is there opportunity for feedback from shippers and/or customers?
   c) What public support, if any, is needed to sustain the terminal?
   d) What techniques can improve efficiency of intermodal transportation?
   e) What management practices have improved coordination between the work units?

4. *Future of intermodal terminals*
   a) What are the critical factors that influence a shipper's decision to use intermodal service?
   b) What are the critical factors that contribute to the success of intermodal terminals?
   c) What are the deterrents to the success of intermodal terminals?

Other questions
Are there any reports that you recommend which describe the operational and administrative aspects of your terminal? (Information such as spatial aspects of the facility, support infrastructure, use of equipment and technology, and staffing would be particularly useful.)

In case of any queries please contact:
Chiranjivi Sarma Bhamidipati
Center for Transportation Studies
351 McCormick Road, PO Box 400742
Charlottesville, VA 22904-4742
Phone: 434-924-3383/1420   Fax: 434-982-2951
Email: csb8g@virginia.edu

APPENDIX B: Demographic and Economic Data for Areas within the Commonwealth of Virginia

Table B1. Demographic and Economic Data for Areas within the Commonwealth of Virginia

Area Code	REGION	Warehouse Truck Tons	Area (in sq miles)	Population	Per Capita Income	Total Employment	Transportation Employment
51001	Accomack County, VA	948058	455.24	39345	16309	17529	327
51003	Albemarle County, VA	171239	722.61	92035	28852	89108	1168
51005	Alleghany County, VA	89590	444.63	16600	19635	13211	327
51007	Amelia County, VA	75644	356.80	12502	18858	3928	96
51009	Amherst County, VA	172582	475.18	32239	16952	12076	259
51011	Appomattox County, VA	122558	333.69	14128	18086	6132	168
51013	Arlington County, VA	61734	25.87	199776	37706	112777	2496
51015	Augusta County, VA	701231	970.36	70910	19744	58112	1765
51017	Bath County, VA	22364	531.86	4814	23092	3015	27
51019	Bedford County, VA	220442	754.50	66507	21582	22871	459
51021	Bland County, VA	57277	358.67	6903	17744	3044	79
51023	Botetourt County, VA	684453	542.66	32228	22218	10577	370
51025	Brunswick County, VA	489299	566.14	17938	14890	6115	337
51027	Buchanan County, VA	2084454	503.88	24409	12788	12025	621
51029	Buckingham County, VA	437569	580.86	16099	13669	4574	113
51031	Campbell County, VA	506505	504.48	52667	18134	24459	729
51033	Caroline County, VA	193955	532.52	26731	18342	6867	216
51035	Carroll County, VA	191731	476.34	29450	16475	9508	343
51036	Charles City County, VA	37654	182.76	7221	19182	2087	254
51037	Charlotte County, VA	116213	474.99	12491	14717	5530	188
51041	Chesterfield County, VA	3779364	425.75	296718	25286	123219	4372
51043	Clarke County, VA	43300	176.62	14565	24844	6744	44
51045	Craig County, VA	214	330.61	5179	17322	1342	10
51047	Culpepper County, VA	393507	381.00	44622	20162	16572	367
51049	Cumberland County, VA	16537	298.45	9465	15103	2431	75
51051	Dickenson County, VA	1474	331.71	16182	12822	4369	324
51053	Dinwiddie County, VA	525987	503.67	25695	19122	7399	93

Area Code	REGION	Warehouse Truck Tons	Area (in sq miles)	Population	Per Capita Income	Total Employment	Transportation Employment
51057	Essex County, VA	107410	257.77	10633	17994	5553	51
51059	Fairfax County, VA	2340638	395.04	1010443	36888	637571	7090
51061	Fauquier County, VA	151293	649.70	66170	28757	24574	476
51063	Floyd County, VA	16722	381.22	14789	16345	4885	147
51065	Fluvanna County, VA	38409	287.37	25058	20338	5269	69
51067	Franklin County, VA	342691	692.08	50784	19605		
51069	Frederick County, VA	1112804	414.63	71187	21080	53743	1123
51071	Giles County, VA	319660	357.33	17403	18396	7963	186
51073	Gloucester County, VA	52834	216.61	38293	19990	11999	219
51075	Goochland County, VA	29838	284.43	20085	29105	7760	146
51077	Grayson County, VA	33385	442.64	16159	16768	6017	33
51079	Greene County, VA	15769	156.58	17709	19478	4474	80
51081	Greensville County, VA	45489	295.44	11006	14632	10253	306
51083	Halifax County, VA	692408	819.30	36149	16353	17691	354
51085	Hanover County, VA	1740372	472.68	98983	25120	47357	838
51087	Henrico County, VA	3287882	238.06	284399	26410	404805	9403
51089	Henry County, VA	832446	382.35	56208	17110	48244	1249
51091	Highland County, VA	564	415.86	2510	15976	1602	27
51093	Isle of Wight County, VA	612196	315.87	34723	20235	14943	244
51095	James City County, VA	270255	142.92	59741	29256	43507	245
51097	King and Queen County, VA	92645	316.26	6903	17236	2150	75
51099	King George County, VA	14539	180.00	21780	21562	12133	304
51101	King William County, VA	285332	275.43	15381	21928	6638	140
51103	Lancaster County, VA	72406	133.14	11519	24663	6195	85
51105	Lee County, VA	18410	437.13	23787	13625	8704	195
51107	Loudoun County, VA	1639384	519.85	268817	33530	79598	8669
51109	Louisa County, VA	679551	497.14	31226	19479	10043	265
51111	Lunenburg County, VA	112184	431.70	13219	14951	4572	93
51113	Madison County, VA	57001	321.42	13613	18636	5181	89
51115	Mathews County, VA	3202	85.68	9184	23610	2661	87

Area Code	REGION	Warehouse Truck Tons	Area (in sq miles)	Population	Per Capita Income	Total Employment	Transportation Employment
51117	Mecklenburg County, VA	474812	623.93	32381	17171	18880	346
51119	Middlesex County, VA	41401	130.30	10615	22708	4194	124
51121	Montgomery County, VA	276527	388.22	84541	17077	37479	303
51125	Nelson County, VA	102047	472.35	15161	22230	5516	104
51127	New Kent County, VA	13039	209.55	16852	22893	4222	76
51131	Northampton County, VA	292041	207.37	13609	16591	6551	71
51133	Northumberland County, VA	92627	192.30	12820	22917	4417	164
51135	Nottoway County, VA	149572	314.65	15572	15552	7744	66
51137	Orange County, VA	1254426	341.70	31740	21107	10812	120
51139	Page County, VA	75327	311.13	24104	16321	10189	97
51141	Patrick County, VA	104933	483.14	19212	15574	8276	252
51143	Pittsylvania County, VA	221578	970.76	61501	16991	52261	667
51145	Powhatan County, VA	13178	261.28	27649	24104	7094	145
51147	Prince Edward County, VA	33716	352.76	20530	14510	10230	65
51149	Prince George County, VA	810385	265.62	36184	20196	13992	137
51153	Prince William County, VA	1870563	337.78	357503	25641		
51155	Pulaski County, VA	573452	320.57	35055	18973	17853	570
51157	Rappahannock County, VA	3684	266.57	7203	23863	3480	38
51159	Richmond County, VA	85606	191.46	9142	16675	3919	24
51161	Roanoke County, VA	931853	250.87	90482	24637	160765	3985
51163	Rockbridge County, VA	162657	599.63	21337	18356	14478	276
51165	Rockingham County, VA	619607	851.15	72564	18795	68081	1345
51167	Russell County, VA	270737	474.66	28790	14863	12328	335
51169	Scott County, VA	39035	536.58	22882	15073	8264	139
51171	Shenandoah County, VA	438808	512.20	40051	19755	19155	344
51173	Smyth County, VA	509460	452.09	32506	16105	18570	265
51175	Southampton County, VA	85262	599.56	17814	16930	17915	264
51177	Spotsylvania County, VA	446145	400.86	119529	22536	25855	789
51179	Stafford County, VA	373209	270.35	120170	24762	26917	844

Area Code	REGION	Warehouse Truck Tons	Area (in sq miles)	Population	Per Capita Income	Total Employment	Transportation Employment
51181	Surry County, VA	80157	279.09	7119	16682	2927	39
51183	Sussex County, VA	285654	490.73	12249	14670	4619	187
51185	Tazewell County, VA	708755	519.74	44608	15282	21073	445
51187	Warren County, VA	600927	213.70	36102	19841	11544	344
51191	Washington County, VA	482755	562.86	51984	18350	25193	371
51193	Westmoreland County, VA	271443	229.18	17188	19473	5462	75
51195	Wise County, VA	37215	404.04	41905	14271	21187	664
51197	Wythe County, VA	462999	463.24	28640	17639	14821	354
51199	York County, VA	1272574	105.65	61879	24560	21960	211
51510	Alexandria city, VA	1629973	15.18	136974	37645		
51515	Bedford city, VA	134728	6.89	6249	15423	22871	459
51520	Bristol city, VA	1334159	12.90	17496	17311	15596	198
51530	Buena Vista city, VA	113931	6.83	6457	16377	2895	4
51540	Charlottesville city, VA	109044	10.26	40315	16973		
51550	Chesapeake city, VA	2596260	340.72	220560	20949	96136	2971
51560	Clifton Forge city, VA	0				1390	12
51570	Colonial Heights city, VA	79820				11210	65
51580	Covington city, VA	551888					
51590	Danville city, VA	1933896					
51595	Emporia city, VA	131971					
51600	Fairfax city, VA	1276607					
51610	Falls Church city, VA	4487					
51620	Franklin city, VA	1000417					
51630	Fredericksburg city, VA	755838				26691	283
51640	Galax city, VA	94347				11562	66
51650	Hampton city, VA	2124907				83073	568
51660	Harrisonburg city, VA	501570					
51670	Hopewell city, VA	2438708				15961	116
51678	Lexington city, VA	52778					
51680	Lynchburg city, VA	2813473				59753	1075

Area Code	REGION	Warehouse Truck Tons	Area (in sq miles)	Population	Per Capita Income	Total Employment	Transportation Employment
51683	Manassas city, VA	704609					
51685	Manassas Park city, VA	7396					
51690	Martinsville city, VA	833936					
51700	Newport News city, VA	1547692				116438	3105
51710	Norfolk city, VA	3836125				238771	7748
51720	Norton city, VA	42062				4970	34
51730	Petersburg city, VA	268218				20706	246
51735	Poquoson city, VA	344				2982	5
51740	Portsmouth city, VA	872498				55294	1659
51750	Radford city, VA	1520355				10037	35
51760	Richmond city, VA	1230296					
51770	Roanoke city, VA	2226038				160765	3985
51775	Salem city, VA	829015					
51780	South Boston City, VA	0					
51790	Staunton city, VA	214022					
51800	Suffolk city, VA	1649612				24707	1127
51810	Virginia Beach city, VA	1041267				215447	2600
51820	Waynesboro city, VA	1047113				13925	199
51830	Williamsburg city, VA	825388					
51840	Winchester city, VA	1981373					

NOTE: Blanks refer to missing data

APPENDIX C: SAS Codes and Data Input Files

SAS Code for evaluation of First Stage of Accessibility Model

```
ODS html close;
ODS graphics off;
options ls=77 ps=58;
ODS graphics on;
ods html;
data file1;
infile 'E:\Accessibility Data\DrayageChoiceProcess.csv' dlm=',';
input TerminalChoice TravelTime Frequency;
run;
proc print data=file1;
run;
title 'Terminal Choice Process';
proc catmod data=file1;
direct TravelTime;
response logits;
weight Frequency;
model  TerminalChoice = TravelTime / predict;
run;
```

Table C1. Input Data for evaluation of First Stage of Accessibility Model

Terminal Choice	Scaled Travel Time Deviation	Frequency (Tons)	Terminal Choice	Scaled Travel Time Deviation	Frequency (Tons)
1	-0.17	36284	1	-0.41	23518
2	0.42	630	2	0.27	295
3	0	1004	3	0	430
1	-0.37	2910	1	-0.32	431
2	0.27	34	2	0.22	0
3	0	49	3	0	0
1	-0.54	41417	1	-0.41	6232
2	0.21	491	2	0.25	68
3	0	288	3	0	67
1	0	117	1	0	328
2	0.27	0	2	0.46	0
3	-0.36	82	3	-0.2	0
1	0.14	29488	1	-0.48	2753
2	0	1193	2	0.26	28
3	-0.05	510	3	0	25
1	-0.19	58048	1	-0.05	31783
2	0.24	2048	2	0.31	399
3	0	865	3	0	581

SAS Code for evaluation of Second Stage of Accessibility Model

```
ODS html close;
ODS graphics off;
options ls=77 ps=58;
ODS graphics on;
ods html;
data file1;
infile 'F:\Accessibility Data\DrayageChoiceProcess3.csv' dlm=',';
input lnProbRatios TTDevDiff;
run;
proc print data=file1;
run;
proc stdize data=file1 out=file2 method = range;
var TTDevDiff;
run;
proc print data=file2;
run;
title 'Terminal Choice Process';
proc reg data=file2;
model lnProbRatios = TTDevDiff / p r;
run;
```

Table C2. Input Data for evaluation of Second Stage of Accessibility Model

Ln(Probability Ratios)	Scaled Travel Time Deviation
4.405125	-0.17
5.473277	-0.37
6.381206	-0.54
3.497196	0.36
2.74949	0.19
4.51194	-0.19
5.686907	-0.41
5.206239	-0.32
5.686907	-0.41
3.497196	0.2
6.06076	-0.48
3.764234	-0.05
2.899683	0.27
1.797553	0.21
2.055192	0.63
2.348618	0.24
2.899683	0.27
2.532306	0.25
2.715995	0.26
3.634436	0.31

SAS Code for evaluation of Truck to Rail Diversion Model

```
options ls=77 ps=58;
ODS graphics on;
ods html;
data file1;
infile 'F:\04 Truck to Rail Diversion Analysis Data\Truck-Rail
Diversion Analysis.csv' dlm=',';
input DORegion RegSpec RailTons TruckTons RDistance TDistance
RTravelTime TTravelTime;
lnRailTruckTonsRatio=log(TruckTons/RailTons);
DistDiff=RDistance-TDistance;
if DORegion=67 then delete;
run;
proc print data=file1;
run;
title 'Truck-Rail Diversion Analysis';
proc reg data=file1;
model  lnRailTruckTonsRatio = RegSpec DistDiff / p r adjrsq;
run;
```

Table C3. Input Data for evaluation of Truck to Rail Diversion Model

Western Heartland Corridor Region FIPS	Region Specific Factor	Rail Tons	Truck Tons	Distance by Rail (miles)	Distance by Truck (miles)	Rail Travel Time (in hrs)	Truck Travel Time (in hrs)
65	0	2120	225985	1329	703	48.1	28.1
68	1	36000	156238	1362	764	49.8	29.3
64	1	238216	1689577	1296	725	46.1	28.5
55	0	37560	1638397	1062	520	38.6	24.4
57	1	349177	800556	1035	655	37.1	27.1
56	0	11320	417179	984	609	36.6	26.2
67	0	71360	855786	1302	947	49.0	32.9
63	0	7720	381806	1065	743	48.3	28.9

SAS Code for evaluation of Safety Analysis Model

```
options ls=77 ps=58;
ODS graphics on;
ods html;
data file1;
infile 'F:\Final\<filename>.csv' dlm=',';
input AADT Length TruckPercentage FATCrashCount INJCrashCount
PDOCrashCount;
TruckAADT=AADT*TruckPercentage/100;
TrkInvCrashCount=(9.5*FATCrashCount+3.5*INJCrashCount+PDOCrashCount);
run;
proc print data=file1;
run;
proc stdize data=file1 out=file2 method = range;
var AADT TruckAADT Length;
run;
```

```
proc genmod data=file2;
model TrkInvCrashCount = AADT Length / dist=nb link=log predicted
residuals;
run;
```

SAS Code for evaluation of Warehouse and Distribution Center Truck Generation Model

```
options ls=77 ps=58;
ODS graphics on;
ods html;
data WarehouseDataset;
infile 'E:\05 Local Warehouse Movements Analysis\Warehouse Movements
Analysis.csv' dlm=',';
input AreaCode WareTruckTons Pop PCI Area TotEmp TranEmp MotorWareEmp
TranServiceEmp CountyIndic;
lnNormWareTruckTons=log(WareTruckTons/Area);
PopDens=Pop/Area;
lnPopDens=log(Pop/Area);
lnPCI=log(PCI);
NormTranEmp=TranEmp/Area;
lnNormTranEmp=log(TranEmp/Area);
if AreaCode=51027 or AreaCode=51045 or AreaCode=51051 or AreaCode=51091
or AreaCode=51195 then delete;
run;
proc print data=WarehouseDataset;
run;
ods select Plots SSPlots;
proc univariate data=WarehouseDataset plots;
run;
proc plot data=WarehouseDataset;
plot lnNormWareTruckTons*lnPopDens;
plot lnNormWareTruckTons*lnPCI;
plot lnNormWareTruckTons*lnNormTranEmp;
run;
title 'Local Warehouse Movement Analysis';
proc reg data=WarehouseDataset;
model lnNormWareTruckTons=lnPopDens lnPCI lnNormTranEmp / influence p r
adjrsq;
output out=outdata p=predval r=resid stdr=stdresid;
run;
proc plot data=outdata;
plot resid*predval;
plot resid*lnPopDens;
plot resid*lnPCI;
plot resid*lnNormTranEmp;
run;
proc univariate plot normal;
var resid;
run;
```