PERFORMANCE-MEASURE BASED ASSET MANAGEMENT TOOL FOR RURAL FREIGHT MOBILITY IN THE PACIFIC NORTHWEST

FINAL PROJECT REPORT

by

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16. Abstract

MAP-21 establishes national objectives to increase productivity and economic efficiency of the nation's freight infrastructure. The recent passage of MAP-21 has placed an emphasis on integrating asset and performance management tools to help transportation agencies better manage the critical transportation infrastructure. Infrastructure performance management expands the more traditional definition of Asset Management to include measurement and reporting of how those assets achieve their targeted operational objectives. While congestion and bottlenecks in urbanized areas readily, and deservedly, catch the attention of policy makers, many miles of multimodal transportation occur prior to freight trips arriving in (or accrue after leaving) urban areas. These miles and the ability to efficiently navigate them directly impact the productivity of the diverse freight transportation system. This project identifies and seeks to remedy performance measure gaps and freight mobility issues as they relate to identifying the appropriate infrastructure capacity to meet demand for both domestic and international economic competitiveness. Further, this research investigates and develops an applied methodology for determining the potential economic viability, including threshold analyses, of freight multi-modal facilities. The focus discerns the attributes, economic and physical characteristics and market situations that are associated with successful and viable facilities, thereby suggesting a framework for economic feasibility of either expanding or adding a freight multi-modal facility.

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Table of Contents

List of Figures

List of Tables

Executive Summary/Abstract

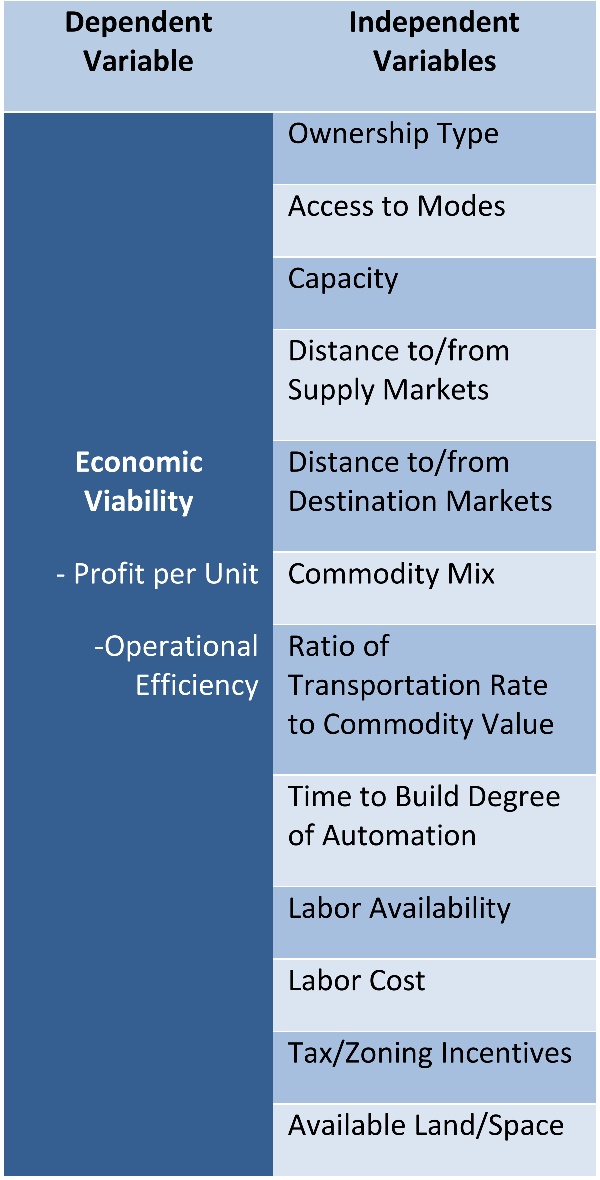
The Moving Ahead for Progress in the 21st Century Act (MAP-21) establishes national objectives to increase productivity and economic efficiency of the nation's freight infrastructure. The passage of MAP-21 has placed an emphasis on integrating asset and performance management tools to help transportation agencies better manage the critical transportation infrastructure. Infrastructure performance management expands the more traditional definition of Asset Management to include measurement and reporting of how those assets achieve their targeted operational objectives. While congestion and bottlenecks in urbanized areas readily, and deservedly, catch the attention of policy makers, many miles of intermodal transportation occur prior to freight trips arriving in (or accrue after leaving) urban areas. These miles and the ability to efficiently navigate them directly impact the productivity of the region's diverse transportation system. The thorough consideration of these segments and the connectivity to their urban counterparts is vital to the development of regionally sustainable and diverse transportation infrastructure in the Pacific Northwest (PNW).

This research investigates and promotes asset of applied methodologies for determining the potential economic viability of intermodal facilities in the PNW. The methodologies are constructed in two phases:

- ❖ Phase one concerns incremental (marginal) changes to the network that usually occur in the form of either proposed new intermodal facilities or proposed updates to current facilities. This paper describes a two-stage measurement tool for prioritizing any such potential investments. In the first stage, the economic viability of the facility is determined using a traditional return-on-investment approach. In the second stage, a regional computable general equilibrium model (CGE) is introduced as a means for measuring the public impact of the investment in terms of willingness to pay. Potential projects that meet the viability condition in the first stage can then be prioritized based on the public's willingness to pay (value to consumers) for its implementation as measured in the second stage.

- ❖ Phase two takes a broader perspective of intermodal feasibility and identifies and rates a set of facility, market, and regional attributes that enable successful operations or enhance their likelihood. We identify the set of existing intermodal facilities as they relate to the current transportation network in the region. From these existing facilities, and identified proposed facilities, we use the identified attributes to generate case study scenarios that reveal the utility and practical implementation of the assessment strategy, producing a guide for transportation personnel in their planning efforts.

Attributes associated with the phase two component may be considered independent variables influences the dependent variable of viability (Figure ES.1)



Dependent Variable	Independent Variables
Economic Viability - Profit per Unit -Operational Efficiency	Ownership Type
	Access to Modes
	Capacity
	Distance to/from Supply Markets
	Distance to/from Destination Markets
	Commodity Mix
	Ratio of Transportation Rate to Commodity Value
	Time to Build Degree of Automation
	Labor Availability
	Labor Cost
	Tax/Zoning Incentives
	Available Land/Space

Figure ES.1 Conceptual Model and Variable Selection

The attribute evaluation process should be considered a first look at the likelihood of viability for a proposed or in place facility. From those facilities that may be considered strong candidates for viability, a more complete marginal analysis should be conducted that implements the two-phased approach defined here. In evaluation of intermodal assets, transportation agencies seek to serve not only the industries that may benefit from such an investment, but also the people of the region as a whole. As such, identifying both the economic viability of the facility to industry, and the generated social welfare become keys to a complete picture of performance of the proposed facility.

Chapter 1 Introduction

1.1 Problem Statement

The Moving Ahead for Progress in the 21st Century Act (MAP-21) establishes national objectives to increase productivity and economic efficiency of the nation's freight infrastructure. The recent passage of MAP-21 has placed an emphasis on integrating asset and performance management tools to help transportation agencies better manage the critical transportation infrastructure. Infrastructure performance management expands the more traditional definition of Asset Management to include measurement and reporting of how those assets achieve their targeted operational objectives. While congestion and bottlenecks in urbanized areas readily, and deservedly, catch the attention of policy makers, many miles of intermodal transportation occur prior to freight trips arriving in (or accrue after leaving) urban areas. These miles and the ability to efficiently navigate them directly impact the productivity of the region's diverse transportation system.

1.2 Background

Efficient freight mobility is the result of successfully balancing the demand for transportation capacity and service with the quantity supplied of those services and capacities. Attaining this balance requires accurate assessment of transportation demand, and the costs and productivity of transportation services supplied, in order to prioritize the provision of facilities and capacity to achieve efficient freight mobility. The need for prioritization arises particularly when funds are limited, as in Idaho and other states, requiring infrastructure investments be allocated to where the marginal returns of mobility are the highest. These economic truisms are as applicable to the public sector as they are to the private sector; however, public sector entities, unlike their private sector counterparts, often experience difficulty in determining the benefits that result from public investments in freight-related infrastructure and activities, in assessing the costs of providing those facilities and in determining the economic feasibility/viability of any infrastructure investment.

These facts are also important for the communities and economic interests of the Pacific Northwest (PNW). A growing number of communities and economic interests in the PNW recognize that efficient freight movement is directly associated to the health of their local and regional economies. As a result, Federal, state and local governments are increasingly being asked to improve freight mobility through operational improvements and new public infrastructure. Intermodal facilities such as truck-to-rail facilities, where goods are transferred from truck to rail for shipment to domestic markets, or through gateways to international markets, are offered as a means of improving the efficiency of the freight movements in some marketing situations. Proposed public investment in such intermodal facilities raises at least two questions that will form the basis of this report: 1) Will the facility succeed in the private market place by generating a sustaining return as a commercial investment? And, 2) Is any public investment justified based on the public benefits (often referred to by economists as externalities) produced?

Many variables, associated with the demand for such a facility and related infrastructure costs and the functions of such a facility, are unknown and are associated with a high degree of risk and uncertainty. The spectrum of current evaluations of potential economic viability and the degree of public benefits reflect the level of uncertainty that exists. Numerous intermodal centers and facilities throughout the nation and world offer indications of how best to narrow the uncertainty and evaluate market opportunities, whether successful or failures.

It is reasonable that intermodal facilities receive some attention as loci of potential investments. Intermodal transportation is often defined as the concept of transporting passengers and freight on two or more different modes in such a way that all parts of the transportation process are efficiently connected and coordinated. When examining freight mobility specifically, intermodal transportation allows the inherent efficiencies of each mode to be realized, while capacity problems in differing links or segments of the system are minimized. Trucks, with low costs of assembly and collection, but significantly higher costs of long haul movement, are combined with railroads, with their high terminal costs but low ton-mile costs. Such intermodal movements, and achieving the potential efficiencies of such movements, are dependent on the structure, location and effectiveness of the intermodal transfer facility. Achieving the efficiencies of intermodal exchange is tempered heavily by the location of the facility, the modes and their access to the facility, and the commodities and their flow to be handled at the facility. The varying quality of service demanded by these commodities can often shift what was perceived as a mode’s competitive cost advantage.

The overall effectiveness and service quality of the facility in aiding the intermodal movements in turn affects the facility’s economic viability. Such effectiveness is reflected in transfers that are coordinated, seamless, flexible and continuous. An intermodal movement requires a system of logical linkages, handled as one continuous through-shipment under the authority of a single freight bill. One challenge of intermodality is to keep the goods moving by reducing delay when a transfer is made from one mode to another. Pundits have described this as a form of warehousing at ‘zero miles per hour’. If the movement of goods is stalled for any length of time during transport or at modal interchange points, it is often referred to as warehousing and not intermodality. This definition continues to evolve and the terms, trans-loading, cross-dock, inventory control, just-in-time distribution, etc., suggest a more complete service function, more than just physical movement that may incorporate the benefits of intermodal movement. Most definitions of intermodal seem to be focused on containerization solely, which may overlook the efficiencies of the warehousing/movement function, and limit the potential opportunities for the complete intermodal concept. Just because a shipment is stored, inventoried, repackaged, etc. does not negate the value of the intermodal movement. Efficiency gained from any sector of the supply chain is efficiency realized in performance measures.

As the gateways to an increasingly global market, transportation corridors are the arteries through which all domestic consumption flows. Transportation networks stimulate and support trillions of dollars in trade, commerce, and even tourism. In the global economy, they enable specialization in the production of goods and services, which, under the law of comparative advantage, stimulates broader economic growth. Increases in efficiency, if achieved from improved intermodal transportation, aid in that growth.

The benefits of such movements has led to calls for unified national transport policy supporting intermodal growth, otherwise the lack of a unified view could create a roadblock to greater efficiency and coordination that would foster even greater intermodal growth. Recent intermodal records in revenues have led to expected record profits as well. Such economic returns are expected to generate interest in development of more facilities and more economically successful facilities.

1.3 Project Purpose and Objectives

The economic competitiveness of all of the jurisdictions contained in the region is highly dependent upon the capacity of the industry in its vast rural landscapes to efficiently traverse the intermodal system. Significant work has been accomplished in the development of performance measures that are highly relevant to the urban landscape; however, substantial work remains to be accomplished in the development of suitable metrics and data surrounding the considerably longer segment of the freight journey prior to arriving at its likely urban destination. The thorough consideration of these segments and the connectivity to their urban counterparts is vital to the development of regionally sustainable and diverse transportation infrastructure in and around the PNW.

The general purpose of this research effort is to investigate and develop applied methodologies for determining the potential economic viability of intermodal facilities in the PNW. This report has two primary objectives in the evaluation of viability. The first concerns incremental (marginal) changes to the network that usually occur in the form of either proposed new intermodal facilities or proposed updates to current facilities. This paper describes a two-stage measurement tool for prioritizing any such potential investments. In the first stage, the economic viability of the facility is determined using a traditional return-on-investment approach. In the second stage, a regional computable general equilibrium model (CGE) is introduced as a means for measuring the public impact of the investment in terms of willingness to pay. Potential projects that meet the viability condition in the first stage can then be prioritized based on the public's willingness to pay (value to consumers) for its implementation as measured in the second stage. This research outlines the basic approach, which can be expanded in future adaptations to include consideration of such issues as market structures, risk and uncertainty, and environmental impacts. Additionally, this approach focuses on incremental project proposals. Future research efforts can benefit from analyses that include changes to how the overall network is used. This type of network analysis is detailed in the literature review section, and may result in more efficient transportation networks although it is a much more complex issue that is not fully considered in this paper. The conclusion of the first objective establishes the necessary data and tools required for such analyses.

The second objective of this report takes a broader perspective of intermodal feasibility and identifies and rates a set of facility, market, and regional attributes that enable successful operations or enhance their likelihood. We identify the set of existing intermodal facilities throughout the state and its neighbors (within 100 miles) as they relate to the current transportation network in the region. From these existing facilities, and identified proposed facilities, we use the identified attributes to generate case study scenarios that reveal the utility and practical implementation of the assessment strategy, producing a guide for agency personnel in their planning efforts.

1.4 Report Organization

The remainder of this report is divided into parts. Part II Conceptual Approach seeks to discuss (a) economic viability and (b) social gains from efficiency in order to provide a background to agency personnel for understanding the motivation and methodology of the proposed tools. Part III Literature Review consists of an in-depth review of Intermodal planning literature as well as a brief introduction to CGE analysis. Part IV Methodology describes the actual implementation of the proposed tool. First, the methodology for determining viability is characterized. Second, the methodology for generating willingness to pay estimates using the CGE model is discussed. Part V considers the application of the identified set of facility, market, and regional attributes. Part VI concludes the analysis with an assessment of selected case studies using the identified attributes, relevant to PNW transportation. Part VII Summary and Conclusions will summarize and conclude.

In order to examine a potential project in terms of its economic merit, we begin by discussing two different economic concepts: viability and efficiency. Viability is the answer to the question of whether the revenues from a project are more than the financial costs associated with it. Efficiency has to do with how the project impacts society in general. In particular, efficiency measures how a project impacts social welfare. In economic terms, a change in social welfare means a change in consumers' ability to get what they want using the resources they have. A positive change, or a net social benefit, means that consumers can generally get more of what they want—either because prices have decreased or their incomes have increased. A negative change in social welfare, or a net social cost, indicates the reverse: consumers can now afford less of what they want.

Chapter 2 Conceptual Approach

2.1 Economic Viability

When a potential improvement to the freight transportation network is proposed, in the form of either a new facility or an upgrade to a current facility, the first step for evaluating the proposal is to determine the economic viability of the facility. In the current context, economic viability refers simply to zero or positive return on investment. That is, a proposed facility is economically viable if it is able to generate enough revenue over the course of its lifetime to cover all of the associated costs. The following figure (Figure 2.1) represents the condition that must be met for a project to be considered economically viable. The remainder of this section discusses the different parts of this viability criterion.

$$\left(\boxed{\text{Revenue}} - \boxed{\text{Variable Costs}}\right)\boxed{\text{Discount}} - \boxed{\text{Fixed Costs}} + \boxed{\text{Salvage Value}} \geq 0$$

Figure 2.1 Economic Viability Criterion

2.1.1 Costs

The cost of adding a facility to the network can be decomposed into several parts (see Figure 2.2). First, some costs are fixed and are paid up front whereas others are recurring and must be paid each year. Fixed costs (f) can include purchasing the land, building the structure, buying equipment, and garnering public support for the project. Second, recurring costs (or variable costs) can also be divided. Two main categories of variable costs are the costs of maintaining and the costs of operating the facility. Routine maintenance costs (m) include fixing broken machinery, updating structures, or renewing permits. Because maintenance costs are likely to increase as resources get old and wear out, we allow m to be an increasing function of time, which we will denote as $m(t)$. Operation or usage costs include paying employees to operate machinery or any other costs associated with day-to-day usage of the facility. We will define usage costs (c) to be costs per shipping unit, so total usage costs will be D^*c, where D is the number of units of transportation demand met by the facility. We will also allow for economies of scale by letting usage costs vary with output. Then total usage costs can be written as $D^*c(D)$[1].

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[1] In this section, parentheses () are used to represent functions and asterisks * are used to represent multiplication.

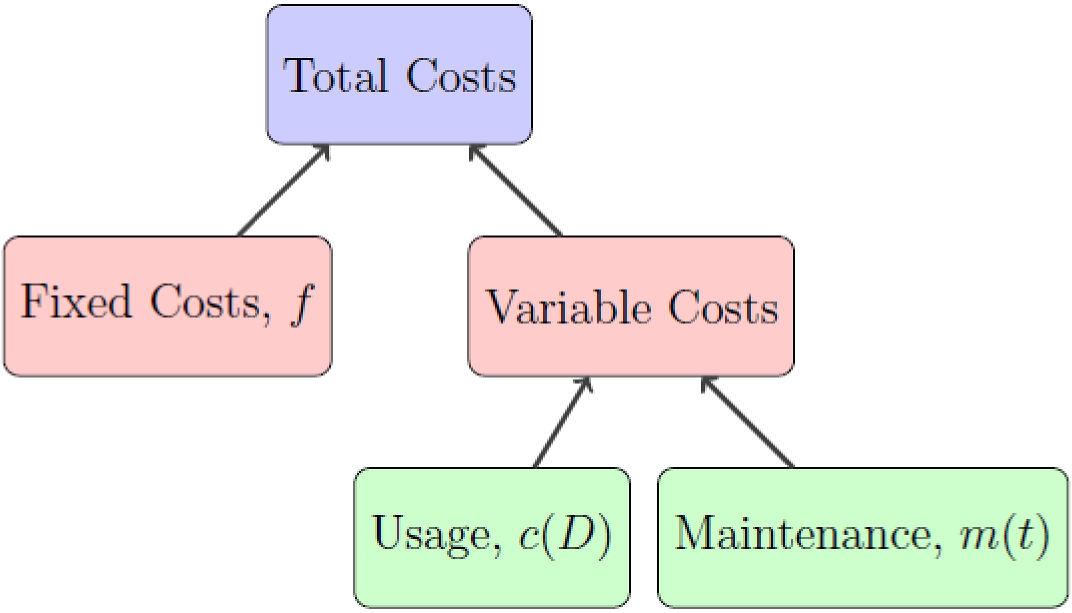


Figure 2.2 Decomposition of Total Costs

2.1.2 Revenue

The revenue depends completely on the demand met by the facility (D) and price that the facility charges for its services (p). We understand that demand decreases as the price of using the facility increases. We assume then that demand is a negative function of price: $D(p)$. Then revenue is equal to $p^*D(p)$, or the price per shipping unit multiplied by the total number of units processed.

2.1.3 Salvage Value

At the end of the life of the facility, it may be the case that some materials can be salvaged; e.g., equipment can be sold or reused elsewhere or the facility can be repurposed. This added value at the end of the lifetime of the facility can act to mitigate some of the costs incurred earlier on. If this is the case, we refer to the value of what can be salvaged as s.

2.1.4 Discounting

When considering economic viability, we want to evaluate the costs and revenue of the facility over its entire lifetime. To do this, we must: 1) estimate how long the facility will be in use, and 2) discount future costs and revenue. If we let δ represent the annual discount factor and n be the number of years that a facility is expected to operate (or the number of years that is otherwise relevant to the analysis), then we can model the viability criterion as follows:

$$\sum_{t=0}^{n} \delta^t \{\text{annual profit in year } t\} - f + \delta^n s \geq 0$$

where t is the number of years that will have passed after the facility is built. Notice that salvage value s is discounted by n years, which is the time between building and eventual shutdown.

2.1.5 Annual Profit

Annual profits are revenue minus variable costs (including both usage and maintenance) for a given year. For year t, this can be described as:

$$p^* D(p) - D(p)^* c(D(p)) - m(t),$$

which can be written equivalently as:

$$D(p)^*[p - c(D(p))] - m(t).$$

2.1.6 Viability Criterion

The criterion that must hold in order for a facility to be economically viable can now be summarized by the following inequality.

$$\textstyle\sum_{t=0}^{n} \delta^t \{D(p)^*[p - c(D(p))] - m(t)\} - f + \delta^n s \geq 0 \qquad (1)$$

We will refer to this condition as Equation 1, or equivalently as the viability criterion. If we assume that all costs and demand for transportation are predetermined, then the only choice of the facility operator is to the set the price of service p. One way to look at the viability criterion is to estimate the price that is necessary to make the inequality hold, and then to determine if that price is reasonable in the relevant market. In practice, because of external social gains associated with the operation of the facility, entities such as federal or local government agencies may see it fit to subsidize the facility (an in-depth discussion on social benefits is contained in the next section (Efficiency and Social Welfare). In the case of public subsidization, a desired price can be entered into Equation 1. The resulting value of the left-hand side (which will be negative if a subsidy is required) will reflect the total amount of subsidy funds necessary to make the facility economically viable.

When determining whether a project meets the viability criterion, several of the variables in Equation 1 must be estimated. Any official project proposals should contain an estimate of economic viability or some other measure of return on investment. Most if not all of the information needed to evaluate Equation 1 should be contained in those proposals. In this report, we propose a methodology for obtaining somewhat independent estimates of a project's economic viability. These estimates can then be used to test or validate the estimates contained in a proposal.

2.2 Efficiency and Social Welfare

In order to understand social welfare from an economic point of view, it is necessary to define some economic terms. Figure 3 below illustrates many of them. The figure is a standard graph representing the market for any good. The y-axis shows the price of the good, and the x-axis measures both the quantity supplied by producers and the quantity demanded by consumers (at a given price). The downward-sloping curve labeled ``Demand“ represents consumers’ willingness to pay for the product or service. The yellow triangle labeled ``Consumer Surplus” represents the happiness of consumers if the price is below their willingness to pay. This surplus can be considered as money left over that someone can then spend on something else.

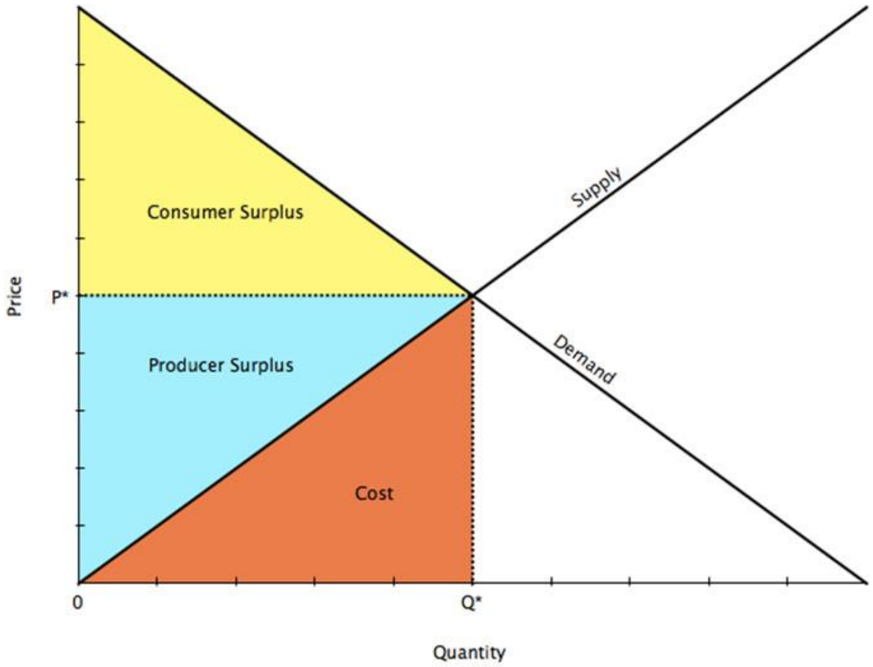


Figure 2.3 Supply, Demand and Surplus

In a similar fashion, the upward sloping ``Supply“ curve represents producers’ willingness to produce and sell. The blue area above the Supply curve but below price, labeled ``Producer Surplus”, represents the benefit to producers for whom the price at which they were willing to sell was lower than the price they received. The combined areas of Consumer and Producer Surplus represent total social welfare. As the structure of the market changes, the Demand curve and/or the Supply curve may shift around. When the combined area of ``Producer Surplus“ plus ``Consumer Surplus” is largest, social welfare is maximized.

In economic welfare analysis, the goal is to understand how benefits shift due to some project or policy. Any shift in the supply curve, demand curve, or price will cause benefits to change. For example, if the supply curve shifts to the right, price will decrease, consumer surplus will increase, and producer surplus will change (see Figure 2.4). Original Consumer surplus A changes to A+B+I+H. Price moves from P* down to P'. Producer surplus changes from C+B to C+D+G. The result then is that if supply increases, then consumers will be better off and producers may be better or worse off (depending on the relative sizes of B and D+G). Total social welfare, though, will increase by the value of D+G+I+H.

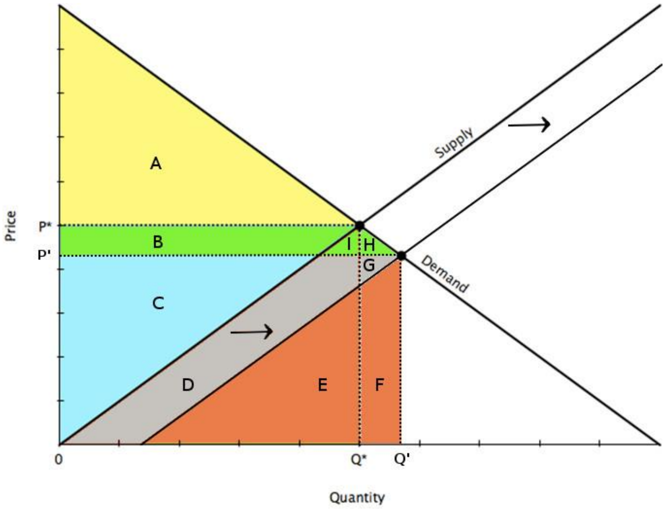


Figure 2.4 The Social Welfare Impact of a Supply Cure Shift

If we imagine that the graphs in these two figures represent the market for Idaho lumber, for example, then the introduction of a new intermodal or loading facility will move the supply curve to the right as described. With a new facility, the lumber producer can now move their lumber more efficiently (the same quantity at a lower cost). This means lower prices for lumber and more consumer surplus. It could also mean more producer surplus, depending on the shape of the producers' costs.

In any case, producers (lumber mills) and society in general will also benefit in ways that are not captured by the figures. This first-stage increase in social welfare means that people in this economy will have more spending money. This money will be spent in other local markets (e.g., at tire stores, restaurants, etc.), which means more money for the people working in those markets. As this money moves around the economy, it creates changes in welfare in each market. For every project or policy change, there is a rippling effect in welfare throughout the economy. These ripples are called general equilibrium effects or secondary effects.

A common measure of welfare change that incorporates these secondary effects—and consequently the measure that will be used in this analysis—is called Equivalent Variation (EV). EV is usually conceived as a measure of how much consumers would be willing to pay to avoid a certain increase in the price of some good. In the context of investments that improve economic efficiency by decreasing the costs of transportation, EV will be a negative value. This reflects the fact that consumers would actually have to be paid a certain amount in order to be just as happy as they would be with the new, lower prices. A more negative EV is then associated with a greater increase in social welfare.

Both the immediate market effects described by the graphs, as well as all secondary effects must be taken into account when attempting to measure the EV associated with a new intermodal facility or a change in an existing facility. In order to deal with the vastly complex nature of these economic changes, a modeling approach called computable general equilibrium (CGE) modeling may be employed. In a CGE model, every sector in the economy is explicitly modeled along with its relationship to every other sector. If we change some aspect in one sector (for example, lower the cost of transporting lumber), all other sectors will shift accordingly. This allows us to examine the potential economy-wide impacts of a project or policy. Additionally, using a CGE framework, general economic benefits can be separated into sector-specific impacts, and changes in the distribution of wealth can also be analyzed.

Chapter 3 Literature Review

3.1 Intermodal Freight Transport Background

3.1.1 What is Intermodal Freight Transport?

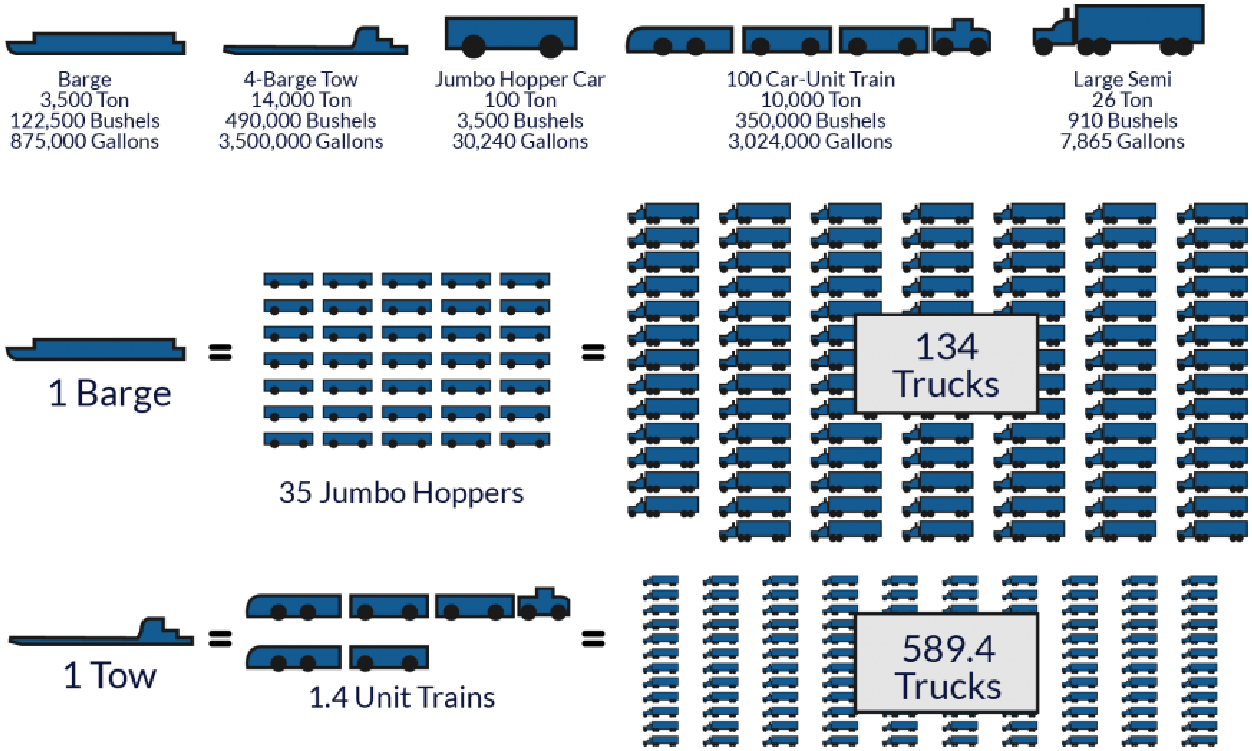
Intermodal freight transport is the shipping of goods by more than one mode between origin and destination. The main forms of intermodal transport are road-rail, rail-barge, or road-barge, but other options such as road-air also exist and are important. We will restrict attention to inland transport and thus we will not address the vast literature on seaports and maritime transport.

In general, goods are first transported from shippers and producers to intermodal terminals on trucks. This operation is called drayage or short haul. At the terminal, the shipments are then either transferred from trucks to another mode (e.g., railcars or barges) or consolidated onto larger trucks. In intermodal shipments, the majority of the transport is done by the non-truck mode, and this portion of the trip is called the long haul. In some cases, the long haul may pass through other terminals for consolidation. Such consolidation terminals are generally rail-rail or barge-barge terminals. The last leg of the intermodal transport process is another round of drayage in which goods are again transferred at intermodal terminals (this time from barges/railcars to trucks) and then delivered by truck to their final destinations. Alternatively, the final destination of interest may be an international port from which goods are shipped to customers overseas. An intermodal service then is defined by an origin and destination, transportation modes, route (including which terminals are used), time, and shipping capacity.

3.1.2 Why is it Important?

Intermodal shipments are becoming increasingly popular. The main idea behind a shift toward intermodal transportation is to take advantage of the relative benefits of multiple transportation modes, and to increase the overall efficiency of how the entire freight network is used. For example, trains and barges are costly to use for short routes but extremely efficient for long hauls.

A shift from mostly truck-based shipments toward intermodal transportation has benefits other than economic efficiency. For example, trains and barges represent fewer greenhouse gas emissions than does truck traffic. Furthermore, a shift away from truck traffic can lead to a decrease road congestion. Quick modal comparison readily reveal the volume of truck traffic that may be alleviated by utilization of barge or rail modes (Figure 3.1).



Source: Port of Lewiston.

Figure 3.1 Modal Cargo Comparison

Many public agencies are and have been making concerted efforts to increase the desirability (by decreasing the costs) of intermodal routes. One of the most important factors that affect the demand that is ultimately met by an intermodal facility is the location of the facility. Much research focuses on the optimal placement of intermodal hubs or terminals. The goal of these efforts is to gain the external public benefits of decreased greenhouse gas emissions and mitigated traffic congestion. In Idaho, intercity congestion and greenhouse gas emissions are not as major of concerns as they are in Europe. Nevertheless, improving intermodal networks does have the benefit of decreasing overall transportation costs and improving social well-being in the region.

3.1.3 Why is it so complex?

A full understanding of intermodal transportation necessarily involves multiple transport modes, multiple types of load units, etc. Additionally, as described by Macharis and Bontekoning (2004), Bektas and Crainic (2007), and Crainic and Kim (2007), intermodal transportation involves the objectives and decisions of disjoint agents including shippers, carriers, facility operators, network planners, and public agencies. Each of these agents also faces decisions at several time horizons (strategic, tactical, and operational). The following section outlines the types of problems that relevant decisions makers encounter and highlights three different review articles that summarize the literature and modeling approaches used to solve these problems. The problems we consider in the current paper focus on freight network performance and terminal viability and are addressed from what is called a strategic or long-term planning perspective. To get a full overview of the background in which viability and efficiency analyses take place—and potentially to direct future research in intermodal planning in ITD—we will discuss the current literature from each aspect of intermodal planning.

3.2 Intermodal Planning

3.2.1 Strategic Planning

Strategic planning focuses on long-term decisions (10-20 years) that require major capital investments. For the drayage operator, strategic problems include cooperating with other drayage firms and determining fleet size. For terminal operators, the design of the terminal is the main strategic problem. This includes decisions about the nature and use of equipment, the type and capacity of storage facilities, and the layout of the terminal. According to Crainic and Laporte (1997), strategic problems that pertain to the network operator include location models, network design models, and regional planning models. The latter models are those that evaluate the products that use an intermodal service, the interaction of intermodal freight with passenger transport, the impact of demand or policy changes, etc. The model of viability and efficiency that we present can be considered a type of such a regional planning model.

3.2.2 Tactical Planning

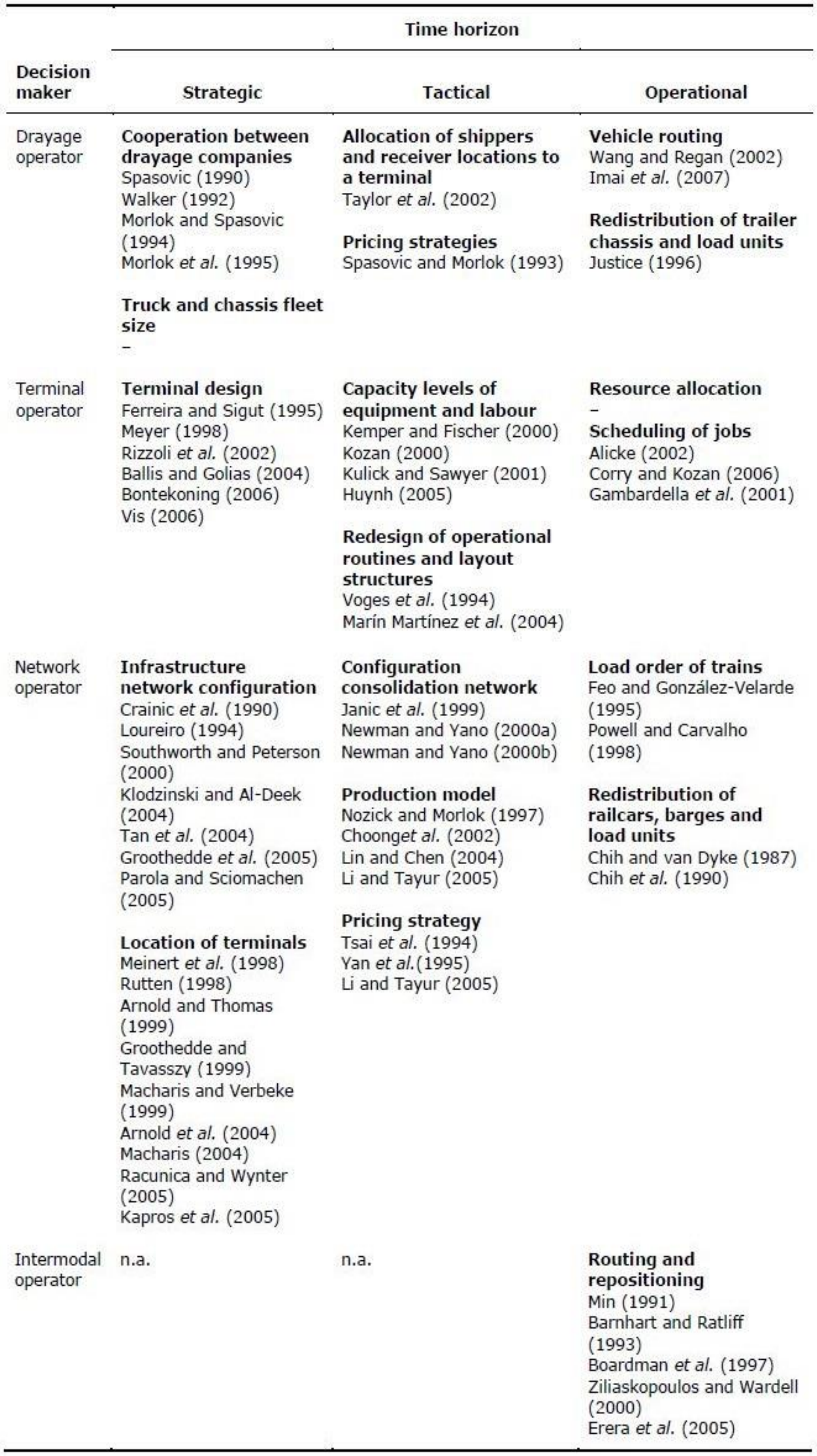
Tactical planning occurs within the time frame of weeks or months and involves the allocation of existing resources within the bounds of current infrastructure. For the drayage operator, this includes matching each origin and destination location with a terminal and developing pricing strategies. For the terminal operator, this includes the allocation of crew and equipment to meet certain capacity levels and the redesign of operational routines and layout structures. For the network operator, Crainic and Laporte (1997) discuss service network design as a major tactical problem. This includes decisions about consolidation networks, route selection, and frequency of service. Network operators must also make asset management decisions, which include plans about the allocation of work among terminals, empty balancing, and the reallocation of crew and equipment among terminals.

3.2.3 Operational Planning

Operational planning consists of day-to-day or real-time decisions. According to Crainic and Laporte (1997) many operational problems are similar to the tactical problems of allocating resources. The main difference is that whereas tactical-level problems involve the ``where“ and ``how” of service decisions, operational decisions are concerned with ``when". In particular, for the drayage operator this includes the routing and timing of truck/container movements between terminals and origins/destinations. For terminal operators, this includes the scheduling of specific tasks in the terminal and load planning. The network operator must also make asset management decisions at the operational level. They must decide the load order of barges and trains, as well as the redistribution of rail cars, barges, and containers each day. Each of the above decision makers is also faced with the problem of crew scheduling and re-planning of tactical decisions when faced with unexpected situations. Additionally, all of the problems facing the intermodal operator are operational. This includes routing of shipments and mode choice.

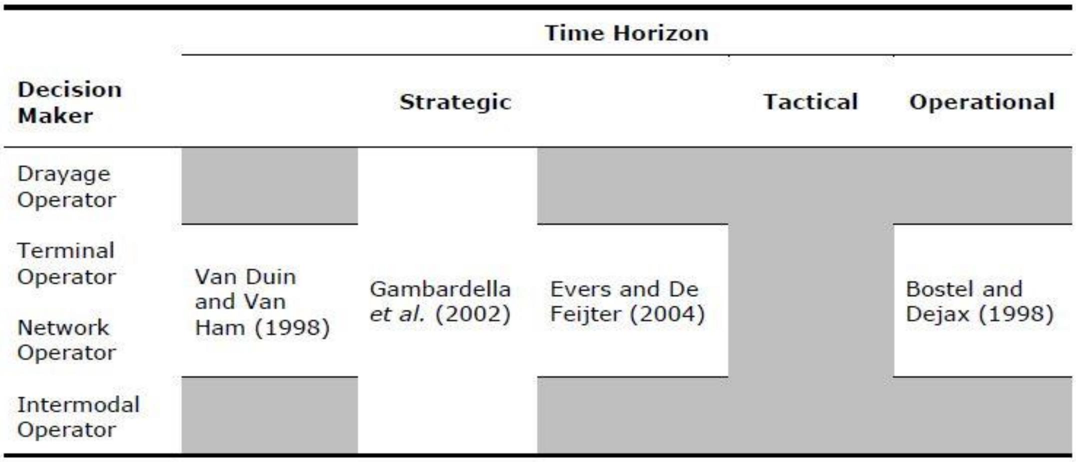
3.3 Review of Planning Model Literature to 2008

Caris et al. (2008) discuss the various planning problems associated with intermodal freight transport and summarize the available operations research models used to solve these problems. The authors divide the analysis into 10 categories that represent a matrix of the three classical decision-making time horizons (strategic, tactical, and operational) with the four main types of decision makers (drayage operators, terminal operators, network operators, and intermodal operators or users of the services)—note that in reality intermodal operators only face operational problems. The categorized list of papers included in this review is summarized in Figure 3.2 (Table 1 from Caris et al. (2008)). The authors also analyze several papers that incorporate multiple decision makers or address problems for multiple planning levels. These papers are included in Figure 3.3 and Figure 3.4 (Tables 2 and 3, respectively, from the same paper).



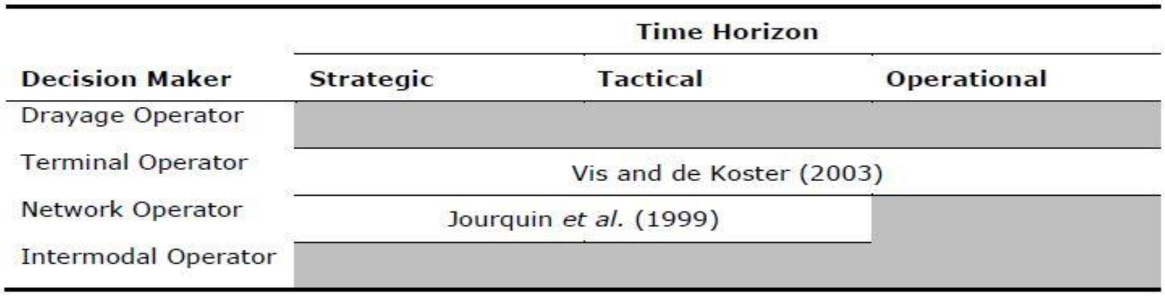
Decision maker	Time horizon Strategic	 Tactical	 Operational
Drayage operator	**Cooperation between drayage companies** Spasovic (1990) Walker (1992) Morlok and Spasovic (1994) Morlok *et al.* (1995) **Truck and chassis fleet size** –	**Allocation of shippers and receiver locations to a terminal** Taylor *et al.* (2002) **Pricing strategies** Spasovic and Morlok (1993)	**Vehicle routing** Wang and Regan (2002) Imai *et al.* (2007) **Redistribution of trailer chassis and load units** Justice (1996)
Terminal operator	**Terminal design** Ferreira and Sigut (1995) Meyer (1998) Rizzoli *et al.* (2002) Ballis and Golias (2004) Bontekoning (2006) Vis (2006)	**Capacity levels of equipment and labour** Kemper and Fischer (2000) Kozan (2000) Kulick and Sawyer (2001) Huynh (2005) **Redesign of operational routines and layout structures** Voges *et al.* (1994) Marín Martínez *et al.* (2004)	**Resource allocation** – **Scheduling of jobs** Alicke (2002) Corry and Kozan (2006) Gambardella *et al.* (2001)
Network operator	**Infrastructure network configuration** Crainic *et al.* (1990) Loureiro (1994) Southworth and Peterson (2000) Klodzinski and Al-Deek (2004) Tan *et al.* (2004) Groothedde *et al.* (2005) Parola and Sciomachen (2005) **Location of terminals** Meinert *et al.* (1998) Rutten (1998) Arnold and Thomas (1999) Groothedde and Tavasszy (1999) Macharis and Verbeke (1999) Arnold *et al.* (2004) Macharis (2004) Racunica and Wynter (2005) Kapros *et al.* (2005)	**Configuration consolidation network** Janic *et al.* (1999) Newman and Yano (2000a) Newman and Yano (2000b) **Production model** Nozick and Morlok (1997) Choonget *al.* (2002) Lin and Chen (2004) Li and Tayur (2005) **Pricing strategy** Tsai *et al.* (1994) Yan *et al.*(1995) Li and Tayur (2005)	**Load order of trains** Feo and González-Velarde (1995) Powell and Carvalho (1998) **Redistribution of railcars, barges and load units** Chih and van Dyke (1987) Chih *et al.* (1990)
Intermodal operator	n.a.	n.a.	**Routing and repositioning** Min (1991) Barnhart and Ratliff (1993) Boardman *et al.* (1997) Ziliaskopoulos and Wardell (2000) Erera *et al.* (2005)

Figure 3.2 Papers involving a single decision level and a single decision maker, from Caris et al. (2008)



	Time Horizon				
Decision Maker	**Strategic**			**Tactical**	**Operational**
Drayage Operator	▨		▨	▨	▨
Terminal Operator	Van Duin and Van Ham (1998)	Gambardella *et al.* (2002)	Evers and De Feijter (2004)	▨	Bostel and Dejax (1998)
Network Operator				▨	
Intermodal Operator	▨		▨	▨	▨

Figure 3.3 Papers involving multiple decision makers, from Caris et al. (2008)



	Time Horizon		
Decision Maker	**Strategic**	**Tactical**	**Operational**
Drayage Operator	▨	▨	▨
Terminal Operator	Vis and de Koster (2003)		
Network Operator	Jourquin *et al.* (1999)		▨
Intermodal Operator	▨	▨	▨

Figure 3.4 Papers involving multiple decision levels, from Caris et al. (2008)

3.3.1 Strategic Models

Strategic drayage models generally consist of cost minimization subject to demand and resource constraints. Several papers in this review, however, find that cooperation between drayage companies can greatly decrease total drayage costs (Spasovic, 1990; Morlock and Spasovic, 1994; Morlock et al., 1995) .

With respect to strategic-level terminal issues, this review highlights how researchers use computer simulation to solve a wide range of terminal design problems. Rizzoli et al. (2002) rely on discrete-event simulation to evaluate the effect of various technologies, government policies, and traffic increases on terminal performance. Balllis and Golias (2004) use simulations to compare different types of expert terminal designs and find that each design is viable for a certain range of traffic volumes. Meyer (1998) simulates rail-rail terminals in a hub-and-spoke network to determine optimal crane capacity and train arrival patterns. Bontekoning (2006) develops a simulation model to identify favorable conditions for the implementation of a new design at exchange facilities. Vis (2006) simulates terminal operations to compare the type of equipment used for storage and retrieval.

Caris et al. (2008) divide the research on strategic network problems into two categories: general infrastructure development and terminal location. Loureiro (2005) and Groothedde et al. (2005) use network models to inform decisions about where to apply public investment in hub capacity and link development in order to decrease costs or improve environmental impacts. Klodzinski and Al-Deek (2004) evaluate the effect of new terminals on local road traffic. Tan et al. (2004) and Parola and Sciomachen (2005) simulate the effect of policies and growth, respectively, on the modal split in a network.

This review also finds three prominent methods for determining the optimal location of terminals in a network. Several articles rely on network models and some optimization technique; e.g., integer programming (Thomas and Arnold, 1999; Groothedde and Tavasszy, 1999; Arnold et al., 2004; Macharis, 2004; Rutten, 1998; Racunica and Wynter, 2005). One paper in the review uses simulations (Meinert et al., 1998). Others develop a multi-criteria analysis approach to choose the best location from a number of possible sites (Macharis and Verbeke, 1999; Kapros et al., 2005) .

3.3.2 Tactical Models

Two tactical-level drayage papers are discussed in this article. Taylor et al., (2002) compare two heuristics for minimizing unproductive miles for drayage companies. Spasovic and Morlock (1993) discuss the development of pricing guidelines for drayage services.

The papers in this review address two types of tactical-level terminal decisions. Several papers discuss how the distribution of equipment and labor capacities affects throughput time or overall quality of service at a terminal (Kemper and Fischer, 2001; Kozan, 2000; Kulick and Sawyer, 2001; Huynh, 2005). Others analyze the redesign of routines and rules for intermodal terminals (Voges et al., 1994; Martinez et al., 2004).

For the network operator, Caris et al. identify articles about the choice of consolidation network and articles about asset management, which they refer to as the type of production model. Janic et al. (1999) evaluates consolidation networks to determine which configurations are most likely to increase the competitiveness of intermodal routes. Production model papers include Nozick and Morlock (1997), Choong et al. (2002), and Lin and Chen (2004). The authors also review papers that consider pricing strategies for network services (Li and Tayur, 2005; Yan et al., 1995; Tsai et al., 1994).

3.3.3 Operational Models

Caris et al. review three papers about drayage problems at the operational level. Imai et al. (2007) and Wang and Regan (2002) propose solutions to a pickup and delivery model with intermodal terminals. Justice (1995) addresses the issue of chassis reallocation to meet demand at terminals.

The main operational planning problem for terminal operators that is addressed in this review is the scheduling of tasks (e.g., loading and unloading) within a terminal (Corry and Kozan, 2006; Gambardella et al., 2001). Alicke (2002) and Rotter (2004) investigate the benefits of the 'mega hub' concept, which replaces the need for shunting at rail terminals.

Most decisions facing the network operator are medium- to long-term planning problems, but Caris et al. find a few articles that address more day-to-day issues. Feo and Gonzalez-Velarde (1995) and Powell and Carvalho (1998) analyze the optimal load order of trains and barges. Chih and Dyke (1987) and Chih et al. (1990) evaluate the redistribution of rail cars, barges, loaded containers, and empty trailers and containers.

All of the intermodal operator's problems are operational. The review highlights several papers that discuss optimal routing and mode choice (Barnhart and Ratliff, 1993); Boardman et al., 1997; Ziliaskopoulos and Wardell, 2000; Min, 1991; Erera et al., 2005).

3.3.4 Review Conclusions

Very few papers consider problems that involve multiple decision makers or integrate multiple planning horizons. Van Duin and van Ham (1998) develop a three-stage model that links terminal location decisions to terminal operating procedures. Gambardella et al. (2002) introduce a simulation model that includes all four decision makers and test the feasibility of different transport plans. Vis and de Koster (2003) outline a summary of the decisions at each planning level for terminal operators, the types of material handling equipment needed, and the quantitative models that are used to solve terminal decision problems. Jourquim et al. (1999) introduces the NODUS model, which combines strategic and tactical decisions of network operators to minimize generalized costs. The NODUS model has since been adopted by others and will be discussed in more detail in the next section.

At the end of this review, Caris et al. conclude that although many operations research techniques have been used and/or extended to analyze various aspects of intermodal planning, many holes in the literature still exist. Little analysis has been done with respect to metaheuristics for determining which operations research approaches are the best for certain problems. Additionally, little research addresses the optimal allocation of resource capacity at terminals. The authors further call for more models that incorporate cooperation between different types of decision makers or integrate the problems faced at different time horizons (e.g., terminal network design and service network design).

3.4 Review of Recent Decision Support Models

Caris et al (2013) is a review of literature on recently developed decision support models for both private actors and public agencies involved in intermodal transportation. The review is a direct supplement to the review by Caris et al. (2008), and it categorizes recent papers into six sections: (1) policy support, (2) terminal network design, (3) intermodal service network design, (4) intermodal routing, (5) drayage operations, and (6) Information and Communication Technologies (ICT) innovations. The review discusses the state of the art and the existing gaps in the research for each section. The authors conclude with a description of perceived trends and general gaps in the overall literature of intermodal planning.

3.4.1 Policy Support

The papers reviewed in the first section support decisions made by policymakers. In particular, these papers analyze the effects of different policies or public investments on the intermodal freight system. This section starts with a set of papers based on three models (referred to as LAMBIT, NODUS, and SIMBA) that make up the support system in Macharis et al. (2011) . The review then discusses several other policy support models from the literature (Floden, 2007; Tsamboulas et al., 2007; Zhang et al., 2008; Yamada et al., 2009; Iannone, 2012; Maia and do Couto, 2013).

The NODUS model was introduced by Jouquin et al. (1999) and uses Geographic Information System (GIS) software to create a virtual network. This virtual network not only represents the links and nodes in the actual transportation network, but also recognizes each operation that can be performed on a given link or node. For example, unloading at a terminal is represented by a different virtual node than transshipping through that same terminal. In this way, total costs can be calculated that incorporate all of the unique services that are used along the way for a specific shipment. Using the NODUS software, a researcher can build a virtual intermodal network to assess total costs, environmental impacts, modal splits, and traffic demands associated with specific network infrastructures and service network designs. This serves as a method for comparing different network configurations to find an optimal design. The NODUS model can also be used to find optimal terminal locations.

The LAMBIT and SIMBA models are both specific to Belgium waterway networks, but they represent the type of analysis that can be done for intermodal networks in any region. Both LAMBIT and SIMBA can use the GIS networks produced by NODUS as inputs. LAMBIT is a GIS-based location model that uses data on transport prices and a shortest path algorithm to find the best routes for every origin/destination combination in the Port of Antwerp region. It can be used to compare the costs of shipping unimodally by road or intermodally using rail or waterways, and can generate market areas for each terminal in the network. SIMBA is a discrete-event simulation software designed to simulate the effect of different policies on the performance of Belgium's waterway network. For more information on SIMBA, see Caris et al., (2010).

Macharis and Pekin (2009) use the LAMBIT model to assess different policy measures aimed to stimulate a shift toward more utilization of intermodal routes. Macharis et al., (2010) use LAMBIT to assess the impact of fuel price increases or the internalization of external costs on terminal market areas. Pekin et al. (2013) add value of time considerations to the total transport costs in the model and highlight the importance of shipment contents in determining the competitiveness of intermodal routes. Finally, Macharis et al. (2011) combine the NODUS, LAMBIT, and SIMBA models to create a fully integrated decision support tool for policymakers in Belgium.

3.4.2 Terminal Network Design

The papers in the terminal network design section add to the literature on optimal terminal locations. The majority of papers reviewed here use some sort of p-hub network location model or alternate approach to determine the number and location of terminals that will minimize network operating costs (Rahimi et al., 2008; Vidovic et al., 2011; Limbourg and Jourquin, 2009;

Ishfaq and Sox, 2011, 2012; Sorensen and Vanovermeire, 2013; Sorensen et al., 2012; Murillo, 2010). According to Zhang et al. (2013), many problems still exist with the current network design models. These include a lack of consideration for economies of scale in terminal handling costs, a lack of connection between terminal network designs and service network designs, a lack of realistic demand models, and long computation times.

3.4.3 Intermodal Service Network Design

According to Caris et al. (2013), intermodal service network design broadly consists of three parts: choosing which services are offered on which routes, determining the frequency of each service, and deciding which consolidation network to use. Woxenius (2007) provides a description of the traditional types of consolidation networks, which are represented by Figure 3.5 (Figure 1 from Woxenius (2007)). The types of networks include direct link, corridor, hub-and-spoke, connected hubs, static routes, and dynamic routes.

Most of the articles reviewed in this section discuss optimal service networks in the context of a specific consolidation framework (Kim, 1997; Newman and Yano, 2000; Caris et al., 2011; Andersen, 2009; Bauer et al., 2009; Woxenius et al., 2013; Caris et al., 2012; Braekers et al., 2012). Only one paper reviewed attempts to assess the optimal consolidation design (Kreutzberger, 2010).

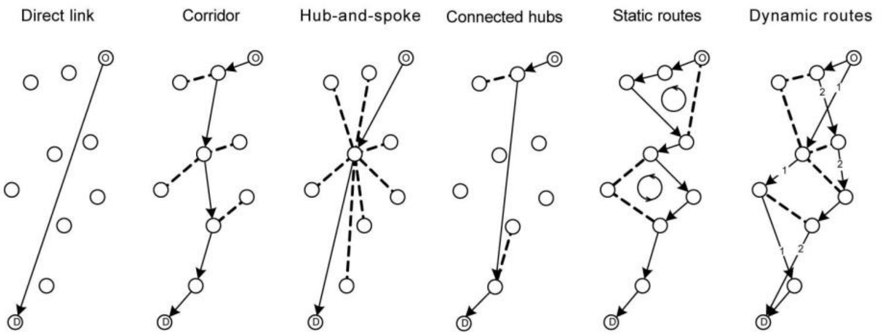


Figure 3.5 Six options for transport from an origin (O) to a destination (D) in a network of ten nodes. Dotted lines show operationally related links in the network designs. In ‘Dynamic routes’, two alternative routes are shown; in all other designs, the routing is predefined, from Woxenius (2007)

3.4.4 Intermodal Routing

This section presents literature about the problem facing shippers who use intermodal networks, which is to determine optimal routes and modes of transport for given origin-destination combinations. Many researchers have developed route choice models that incorporate various objectives such as costs, time, time variability, transport risk, and average length of haul (Min, 1991; Yang et al., 2011); Cho, 2012; Verma et al., 2012). Chang (2008) suggests that the future route planning models should incorporate multiple objectives simultaneously, time window constraints, and economies of scale.

3.4.5 Drayage Operations

Drayage operations represent a large proportion of the total costs of intermodal shipping, but few papers address drayage problems from an intermodal context. Some of these papers are summarized in this section. The basic problems of drayage operators are vehicle routing or pickup and delivery problems, for which solutions can be found in other literature.

3.4.6 ICT Innovations

Intermodal transport systems involve decision making agents with diverse interests and levels of control. According to Crainic and Kim (2007), Information and Communication Technologies (ICT) have the potential of improving timeliness and quality of data, data flows, real-time controls, and coordination among agents. Nevertheless, very little research has been done in this area. Dullaert et al. (2009) create a communication system with the goals of (1) matching supply with demand, (2) enabling the tracking of shipments, and (3) improving real-time reaction to unexpected problems. Dotoli et al. (2010) create a simulation that incorporates the introduction of ICT for some regions to test the potential impact of such technologies on intermodal systems.

3.4.7 Review Conclusions

According to Caris et al. (2013), since the 2008 review, the new literature has developed more mathematical models for solving intermodal problems, incorporated more dynamic features into analyses, and given more focus to environmental impacts than previous papers. The main hurdles that future researchers will have to overcome are the coordination of diverse actors, the large and complex scale of intermodal network projects, and the limited availability of good data (due to both proprietary concerns and difficulty in data collection/transmission). The Caris et al. suggest that future research efforts should include more links between terminal network design and service network design, more complex solutions for routing problems, more dynamic approaches to drayage problems, the development of more ICT tools, and more fast heuristics for complex problems.

3.5 Intermodal Planning Literature Review from 2005 to 2013

By strategic, tactical, and operational planning levels, SteadieSeifi et al. (2014) describe current literature addressing mostly decisions regarding network management. For each planning level, the authors discuss the conceptual and mathematical models used, the solution methods employed, and opportunities for future research based on identified gaps.

3.5.1 Strategic Models

At the strategic level, the review highlights the current literature on network design. The most common consolidation plan is the hub-and-spoke network and most research in this section analyzes the optimal location-allocation of such networks. For an extensive study of hub location problems, the review directs the reader to Alumur and Kara (2008). SteadieSefie et al. (2014) also outline the various types of hub-and-spoke allocation models (single-allocation, multi-allocation, r-allocation, and hierarchical allocation) and the solution concepts employed to solve such models. The authors point out that these problems are complex and current solution algorithms are inadequate and inefficient but improving. Although adding complexity will make the models even harder to solve, the authors suggest several elements that are virtually missing from current network design models. These include capacity restrictions, fixed costs of building hubs, transshipment (switching between modes) and associated costs, empty unit storage, cooperation and competition between carriers, and environmental issues.

3.5.2 Tactical Models

Tactical decisions discussed in this review center on network flow planning (NFP) or service network design (SND). SND includes decisions about service frequency, capacity, equipment planning, and routing, whereas NFP focuses solely on the flow of goods through the network. Most papers in this section discuss SND problems, which can be either static or dynamic. For a detailed review of dynamic SND problems, refer to Wieberneit (2008). In discussing solution methods, SteadieSefie et al. (2014) suggest that heuristics and metaheuristics are the most used methods for these complex problems, with the Tabu Search method being the most popular. Unfortunately, as the authors point out, no real benchmarks exist for evaluating the efficiency of and thus comparing the existing algorithms. The review further suggests that future SND models better incorporate asset management decisions, explicit transshipment costs, time windows, uncertainty, and plans for how to react to unexpected incidents.

3.5.3 Operational Models

SteadieSefie et al. (2014) stress the importance of operational models that provide real-time analyses quickly and efficiently, but find few models at this level. The authors divide the articles that do address operational issues into two categories: resource management, and itinerary re-planning. Resource management includes the allocation and reallocation of fleet capacity and empty containers or trailers. Itinerary re-planning describes the responses to unanticipated events (demand shocks, emergencies, etc.). For a more detailed review of the literature on operational problems of terminal operators, refer to Stahlbock and Vos (2008). For a more detailed review of drayage problems, refer to Parragh et al. (2008), or Laporte (2009) for general vehicle routing problems. For a more detailed review of Information and Communication Technologies (ICT) and other so-called Intelligent Transportation Systems (ITS), refer to Crainic et al. (2009).

3.5.4 Review Conclusions

Though SteadieSefie et al.'s (2014) approach and selection of articles differs from Caris et al. (2008) and Caris et al. (2013), the conclusions from the reviews are quite similar. Many mathematical models and complex algorithms have been developed for the study of intermodal networks, but many holes still exist. According to SteadieSefie et al. (2014), these holes include: a more diverse study of various consolidation approaches (most are hub-and-spoke), more trade-offs between multiple objectives (e.g., cost and time), more dynamic and stochastic models, the incorporation of backward flows in the planning of forward flows, the simultaneous planning of multiple resources (e.g., vehicles and crew), and the consideration of multiple agents or multiple planning levels simultaneously. The authors then conclude with an appeal to a paradigm shift in terminology, that the use of ``co-modality“ and/or ``synchromodality” in place of ``intermodality" highlight the necessity of incorporating multiple decisions into one system.

3.5.5 Summary and Implications

Our two-step approach for this project to evaluating viability and efficiency attempts to incorporate many of the applicable aspects of intermodal planning discussed above. As mentioned earlier, the current approach can be classified as a strategic regional planning model. The main contributions of our model are 1) the focus on evaluating incremental changes to the network individually, and 2) the use of the CGE model to determine changes in economic surplus, which can be considered as a new heuristic for evaluating a freight network.

Many of the terminal location or network design models that use total network costs as the bottom line are focused on evaluating the entire network at once. It becomes increasingly complicated to include details such as fixed building costs and realistic demand models. Separating the analysis into viability and efficiency means that in the first stage, we can include a more robust model of a proposed upgrade. We can include building costs, economies of scale, etc., and we never have to directly compare the costs of different proposals. The only consideration during the viability stage is whether a particular facility can generate enough demand at a given priceto cover its own costs. We can also include a realistic demand model based on prices (including getting to the facility, using the facility, the value of time, etc.) and capacity. The only comparison needed between possible projects is the economic impact on the region obtained using the CGE model in the second stage.

Similar to the trends described above, future adaptations of our approach may be expanded to include: market structure considerations (cooperation or competition between companies); risk and uncertainty (variability in time/costs, probability of damage/loss); and/or environmental impacts. Additionally, the current approach is specifically concerned with evaluating the potential impact of incremental project proposals, which take current network and service designs as given. We understand that overhauling an entire network by adjusting consolidation designs or overall networks flow patterns, etc. can result in a more efficient transportation system. Such large-scale considerations are also likely to be considered in future research and planning efforts.

3.6 Rural Congestion – An Overview

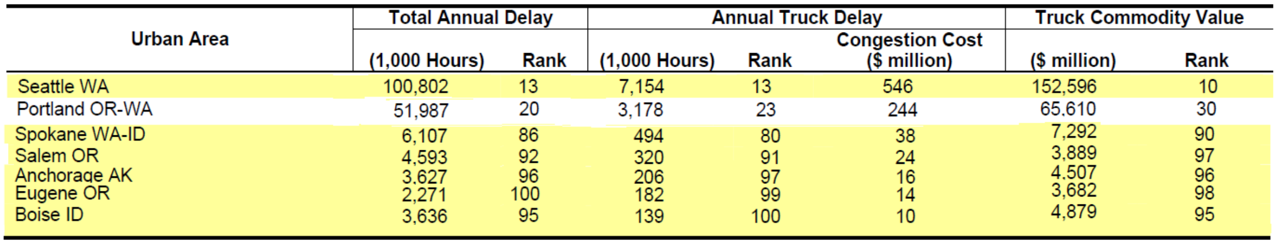
To transport goods to suppliers, manufacturers and markets, truck traffic travel on urban and rural highways during different times of the day. Many of the trips conflict with commuter trips during morning, noon, and afternoon peak periods. With many manufacturers in North America operating in just-in-time (or lean) manufacturing process, efficient delivery timing of components to reduce the amount of inventory warehouse space and reliable estimates of truck travel times are key components of these systems.

Urban and Rural congestion affects truck productivity and delivery times and can also be caused by high volumes of trucks, just as with high passenger vehicles and other non-truck volumes. One difference between car and truck congestion costs is important; it is intuitive that some of the $27 billion in truck congestion costs in 2011was passed on to consumers in the form of higher prices. The congestion effects extend far beyond the region where the congestion occurs. In its 2012 Mobility report, Texas Transportation Institute (TTI) developed a methodology to estimate the value of commodities being shipped by truck and through urban areas and in rural regions. The commodity values were matched with truck delay estimates to identify regions where high values of commodities move on congested roadway networks.

The truck commodity data published in the 2012 TTI's mobility report points to a correlation between commodity value and truck delay—higher commodity values are associated with more people; more people are associated with more traffic congestion. Bigger cities consume more goods, which means a higher value of freight movement. While there are many cities with large differences in commodity and delay ranks, only 23 urban areas are ranked with commodity values much higher than their delay ranking. The data also illustrates the role of long corridors with important roles in freight movement. Some of the smaller urban areas along major interstate highways along the east and west coast and through the central and Midwestern U.S., for example, have commodity value ranks much higher than their delay ranking. High commodity values and lower delay might sound advantageous—lower congestion levels with higher commodity values means there is less chance of congestion getting in the way of freight movement. At the area wide level, this reading of the data would be correct, but in the real world the problem often exists at the road or even intersection level—and solutions should be deployed in the same variety of ways, (Schrank et al. 2012).

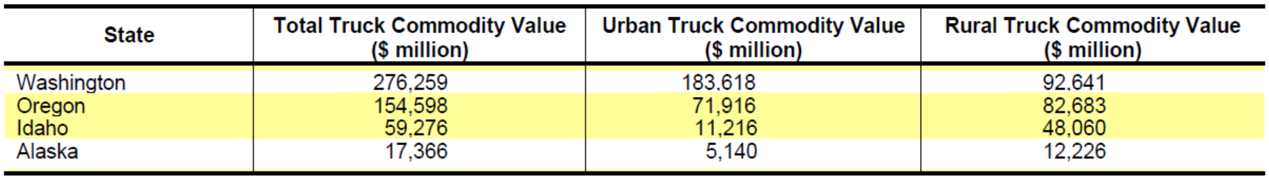
Urban and rural corridors, ports, intermodal terminals, warehouse districts and manufacturing plants are all locations where truck congestion is a particular problem. Some of the solutions to these problems look like those deployed for person travel—new roads and rail lines, new lanes on existing roads, lanes dedicated to trucks, additional lanes and docking facilities at warehouses and distribution centers. New capacity to handle freight movement might be an even larger need in coming years than passenger travel capacity. Goods are delivered to retail and commercial stores by trucks that are affected by congestion. But "upstream" of the store shelves, many manufacturing operations use just-in-time processes that rely on the ability of trucks to maintain a reliable schedule. Traffic congestion at any time of day causes potentially costly disruptions. The solutions might be implemented in a broad scale to address freight traffic growth or targeted to road sections that cause freight bottlenecks. Other strategies may consist of regulatory changes, operating practices or changes in the operating hours of freight facilities, delivery schedules or manufacturing plants. Addressing customs, immigration and security issues will reduce congestion at border ports-of-entry. These technology, operating, and policy changes can be accomplished with attention to the needs of all stakeholders and can produce as much from the current systems and investments as possible. Table 3.1 present truck commodity value and truck delay for major urban areas in the Pacific Northwest region and Table 3.2 presents truck commodity value for the four states in the Pacific Northwest region based on 2011 data (Schrank et al. 2012).

Table 3.1 2011 Truck Commodity Value and Truck Delay for Major Urban Areas in the Pacific Northwest Region



Urban Area	Total Annual Delay		Annual Truck Delay			Truck Commodity Value	
	(1,000 Hours)	Rank	(1,000 Hours)	Rank	Congestion Cost ($ million)	($ million)	Rank
Seattle WA	100,802	13	7,154	13	546	152,596	10
Portland OR-WA	51,987	20	3,178	23	244	65.610	30
Spokane WA-ID	6,107	86	494	80	38	7,292	90
Salem OR	4,593	92	320	91	24	3,889	97
Anchorage AK	3,627	96	206	97	16	4.507	96
Eugene OR	2,271	100	182	99	14	3,682	98
Boise ID	3,636	95	139	100	10	4,879	95

Table 3.2 2011 Truck Commodity Value for the Four States in the Pacific Northwest Region



State	Total Truck Commodity Value ($ million)	Urban Truck Commodity Value ($ million)	Rural Truck Commodity Value ($ million)
Washington	276,259	183.618	92.641
Oregon	154,598	71,916	82,683
Idaho	59,276	11,216	48,060
Alaska	17,366	5,140	12,226

In their 2005 report, Cambridge Systematics and Texas Transportation Institute (TTI) identify different sources of recurring (capacity related) and non-recurring (traffic incidents, weather, and work zones) congestion and state that the identification of sources of congestion is important for developing strategies to mitigate the effects of congestion, (Khanal, 2011). The report also provides various examples of performance metrics for congestion grouped into categories related to throughput, average congestion conditions, and reliability. Metrics listed under throughput include: vehicle-miles of travel (VMT), truck vehicle- miles of travel, and person-miles of travel. Those under average congestion conditions are: average travel speed, travel time, number and percent of trips with travel times greater than 1.5 times the average travel time, number and percent of trips with travel times greater than 2 times the average travel time, travel time index (which will be defined below), total delay, bottleneck delay, traffic incident delay, work zone delay, weather delay, ramp delay, delay per person, delay per vehicle, percent of VMT with average speeds < 45 mph and < 30 mph, and percent of day with average speeds < 45 mph and 30 mph. Performance metrics listed under reliability are: planning time, planning time index, and buffer index.

Travel time index has been defined as the ratio of actual travel time to ideal (free-flow) travel time. It appears from this definition that the travel time index can be defined for peak as well as non- peak periods. Travel time variability is noted as a different component of traffic congestion that needs a different set of solution strategies. They identify three indices that describe reliability: Planning Time, Planning Time Index, and Buffer Index. Planning time is described as the travel time that will allow a buffer or extra time to the traveler so that a high rate of on- time arrival can be ensured. The 95th percentile travel time is used as the planning time. Planning Time Index is the ratio of Planning Time to free-flow (ideal) time. Buffer Index is the ratio of (Planning Time – average travel time) to the average travel time. The report identifies the following transportation system performance aspects as requiring monitoring: safety, physical condition, environmental quality, economic development, quality of life, and customer satisfaction. They state that congestion is intertwined with all of these since higher congestion levels lead to their degradation.

Khanal (2011), completed a project for the Idaho Transportation Department (ITD) to define and quantify rural congestion on Idaho's two-lane roads. He started the project by contacting ITD's six district engineers a request for a list of six most congested locations in their districts and to describe their approach to dealing with the congestion. There were subsequent contacts with the district engineers through video conference, email, and in-person interviews during field visits to the districts. Input was also sought from department of transportation engineers from Idaho's neighboring states.

The project team conducted a comprehensive literature review on the topic and came up with a suggested list of congestion measures to use in the quantification of congestion. The congestion measures were based on travel time and the project team determined that the use of portable devices based on Bluetooth technology would be best to collect travel time data from remote and isolated sections of selected two-lane roads in the state. The project team then selected representative road segments from each of the six ITD districts and ITD's Roadway Data Unit assumed the responsibility of setting up the portable Bluetooth units to collect travel time data and to provide volume data for the segments over a number of days that included the weekend.

The project team analyzed the data and recommended Buffer Index values of 0.15 and 0.14 as the threshold of congestion for peak periods during weekdays and weekends. The corresponding values for non-peak period were determined to be 0.18 for both weekdays and weekends. The project team also concluded that current volumes on Idaho rural roads have less effect on travel times relative to geometric characteristics and speed limits and that portable Bluetooth readers were an effective tool to collect travel time data on rural roads. The project team also concluded that thorough modeling of congestion sources allows the state to make more quantitative decisions on highway design improvements.

The published report recommends that the results from this study be used as a baseline for future travel time data collection and analysis. They also recommend that travel time data collection on selected road segments of interest be collected at periodic intervals, annually, if possible. Coterminous volume data should also be collected contemporaneously with the travel time data. Records of travel time and volume measurements should be maintained, and used in trend analysis, which can then be used in identifying thresholds for congestion. And volume data must be collected within the study segment for accurate modeling Implementation of further rural congestion data collection activities are under consideration by ITD.

Gattis et al. (1995) investigated rural roadway capacity and congestion issues. Activities included: survey, literature review of saturation flow rates for freeways, literature review of saturation flow rates and lost times for intersections, review of passing/climbing lanes, evaluation of passing/climbing lane software, field studies of passing/climbing, accident histories and delays for different access control types.

Saturation flow rate data was used to determine congestion level on a roadway. The practice of assuming < 5 sec headways as constituting delay was tested and found to be questionable under certain circumstances. The authors determined that congestion is a matter of expectations: if the public expects a certain freedom of operation and that freedom is not met, then congestion is perceived to exist. The project was conceived as an exploratory, Phase I effort. By a 2 to 1 margin, respondents to the survey said they did have rural traffic congestion and about half did not have methods to assess levels of congestion.

The Washington State Department of Transportation base their congestion performance measure on percentage of vehicles traveling at or below the "maximum throughput speed" (about 51 mph) or about 70% of the posted speed, (WSDOT, 2010). Any lower speed is considered to cause delay (congestion). Road segments with speeds at or below 35 mph (60% of the posted speed limit) are considered to be severely congested. The typical highway posted speed limit in Washington is 60 mph. According to this report highways are not necessarily operating at their maximum efficiency when all vehicles are moving at 60 mph. The report states that as congestion increases, speeds decrease and fewer vehicles pass through the road section. Throughput may decline from a maximum of 2000 vehicles per hour (vph) per lane at speeds between 42 – 51 (100% efficiency) mph to as low as 700 vph per lane at speeds of less than 30 mph (35% efficiency).

The Oregon Department of Transportation (ODOT) recommends the use of the v/c ratio to assess the quality of flow on a roadway, (Gregor, 2004). They state that "v/c indicates how close a roadway is operating to the threshold between smooth traffic flow and chaotic (stop-and-go) traffic flow during ordinary peak-hour traffic conditions". The value of 0.70 is considered to be the point where traffic speeds drops noticeably below free flow speeds, and as such, this value is the threshold used by ODOT to classify a road segment as congested.

Colorado DOT published a study on how various states defined both urban and rural congestion (CDOT, 2000). Various states were surveyed. The survey results showed that most states define rural congestion in terms of a volume to capacity (v/c) ratio or a level of service (LOS). Colorado DOT defines rural congestion in two-lane rural highways when the volume to v/c ration exceeds 0.85. New Mexico DOT set the congestion level and a v/c ratio of 0.75. Arizona DOT and Florida DOT define rural congestion in two-lane rural highways when the LOS, estimated using the Highway Capacity Manual (HSM) 2010 procedures, is lower than LOS B. Washington DOT defines rural congestion either at LOS of C or a v/c ratio of 0.35. ITD defines two level of rural congestions at two-lane rural highways: near congestion at v/c ration of 0.39 and at congestion at v/c ration greater than 0.62. ITD also define rural congestion on any passing lane segment if the Average Annual Daily Traffic (AADT) on the segment is greater than 2500 vehicle per day, the percentage of truck traffic exceeds 12%, the segment length is more than 2 miles, and the segment is in rolling or mountainous terrain.

Al-Kaisy et al. (2010) introduced a measure to estimate performance on two-lane highways called, percent impeded. The study notes that in rural areas two-lane highways can be characterized by relatively low design standards, higher speeds, and low traffic volumes. In addition, passing maneuvers are restricted and often performed in the opposing lane where sight distance and traffic streams permit. Limited passing opportunities and slow moving vehicles tend to result in higher impacts on mobility, generally in the formation of platoons. Therefore the level of platooning can be used as a performance measure for two-lane highways and an indicator of the degree of freedom to pass slower traffic.

For a vehicle to be impeded it is assumed that (1) a relatively short headway exists ahead of the impeded vehicle, and (2) the travel speed is less than the desired speed of the impeded vehicle. This method classifies vehicles into “slower” and “faster” vehicles. A slow vehicle is the lead vehicle in the platoon, and the faster vehicles are those that are impeded and become part of the platoon. The desired speed refers to a vehicle speed that is independent of (not influenced by) the vehicle traveling ahead. The method uses two probabilities in estimating the percentage of vehicles impeded. The probabilities are: *Pp* – probability of a vehicle being part of a platoon based on the time headway definition of a platoon, and *Pi* – probability of a vehicle being impeded and end up traveling at a less desirable speed.

Pi was estimated by first establishing the desired distribution of speeds for all vehicles in the traffic stream. These vehicles were identified from time headway data and include those away from platoons as well as the lead vehicles in platoons. Cumulative distribution curves were generated from the distribution of speeds. Then from the average speed of slower vehicles the probability of a vehicle being impeded was estimated from the cumulative distribution curves of desired speeds. Once the two components of probabilities were estimated the percentage of vehicles impeded was calculated as PI = *Pp* x *Pi*.

Yu and Washburn suggested that travelers are less concerned about individual segments as they are with their entire trip along a highway, (Qingyong and Washburn, 2009). A facility-based analysis would address the features along an extended length of highway in combination with single performance measures. From the viewpoint of travelers and transportation engineers, a facility-level analysis is more practical and meaningful than a segment-level analysis. This paper introduces a methodological framework that can be used to assess the operational performance of extended lengths of two- lane rural highways that may contain features previously mentioned.

The authors considered various candidate service measures based on the features of two- lane highways and intersection control, such as, volume/capacity (v/c), ATS, PTSF, travel time, percent free-flow speed, density, and delay. They chose percent delay (PD) as the most appropriate single service measure to identify interrupted-flow of a two-lane highway with signalized intersections. The definition of PD is the ratio of delay to free-flow travel time. Delay is the average travel time incurred traveling on the facility in excess of the free-flow travel time. Percent delay is a measure that reflects driver’s freedom to maneuver in the traffic stream as well as traffic control, geometric features, and heavy vehicles influence on speed reductions.

Al-Kaisy and Karjala (2010) investigated car following interactions on two-lane highways with the aim of identifying conditions where vehicles are considered free-flowing. Since the commonly used performance measure on two-lane roads, the percent time spent following (PTSF), is a function of the percentage of free-flowing vehicles, the percentage of free-flowing vehicles in the traffic stream is a measure of quality of flow. Their research used speed and time headway between successive vehicles to establish a headway threshold for free-moving vehicles.

Graphs of average speed of vehicles traveling at headways at or above a given headway were plotted against headways. The graphs revealed that average speed increased at a decreasing rate as headway increased until a threshold value beyond which the average speed remained constant. This threshold value was around 6 sec. So the authors conclude that car following interactions cease beyond a headway value of 6 sec. Based on this research, using the percentage of vehicles traveling at headways of 3 sec or less as a surrogate measure of PTSF cannot be supported.

The research performed further analysis to determine whether interactions between cars exist for all vehicles traveling at headways of 6 sec or less. In other words, the researchers investigated whether some drivers travel at short headways by choice even when passing opportunities exist. To investigate this question data from 4-lane highways were analyzed. The authors found that a significant number of drivers choose to travel at relatively short headways while following other vehicles even when passing opportunities exist. The implication of this finding is that a short headway alone is not a predictor of impedance caused by a slow moving lead vehicle in a platoon.

Catbagan and Nakamura (2008) examined desired speed distributions of drivers on two-lane highway. As have been noted by numerous researchers, user dissatisfaction is caused by the inability to drive at desired speeds because of a slower lead vehicle. Current definitions of following vehicles are based on headway alone. A follower can be more logically defined as a vehicle traveling below its desired speed. Desired speeds of different drivers vary significantly; the variation makes it difficult to assess whether a vehicle is constrained on the basis of directly accessible time headway or speed data alone. The authors of this paper developed desired speed distributions for a two-lane road for various traffic, weather, and ambient conditions to form 64 data sets for analysis. The desired speed distributions were estimated by using a mathematical approach, the modified Kaplan-Meier approach. Their research was limited to two-lane highways with restricted passing; all data were collected during uncongested conditions. Sensors that detect time of passage, speed, detected length, and occupancy were installed 6 m apart on each lane in both directions. Sensor data were used with video data to classify vehicle into four types.

Karlaftis and Golias (2002) address the relationship between traffic speeds and traffic stream characteristics for two-lane roads in Greece. Characteristics mentioned are heavy vehicle traffic and opposing lane traffic. Under the methodology section the authors explain that all previous research have used either linear regression or neural networks both with satisfactory results; however, they mention that the use of neural networks only predicts vehicle speeds and therefore cannot be used to infer relationships between traffic speed and traffic flow. They also suggest that the linear regression implies a hypothesis with an underlying function where the parameters are linear. According to the authors this cannot be justified theoretically or empirically. To overcome this, the authors suggest a Box-Cox regression model, basically a method of generalizing the linear model.

3.7 CGE Literature Review

In addition to direct benefits and costs, infrastructure investment can often have secondary effects in the economy. These effects, generated by efficiency gains in the network, could result in changes in the number of jobs, the total output, or the value added of various sectors in the region. It is important to be able to model the relationship between primary transport benefits and potential economic growth effects (Banister and Berechman, 2001). CGE analysis is a powerful way of studying such changes in a regional economy given some policy or project. The seminal work on CGE modeling is attributed to Johansen (1964) and as a blend of neoclassical theory applied to contemporary policy issues (Bandara, 1991). Shoven and Whalley (1984) developed the method into the highly useful, applied tool it is today.

Typically, a CGE model is generated using a combination of classical economic assumptions (such as zero profit, market clearance, and normal goods) and regional data from a social accounting matrix (SAM). The specific parameters in the models are generally calibrated to coincide with a benchmark period (Partridge and Rickman, 2010). Some aspect of the model—e.g., a parameter value or an elasticity—is then changed and the model is resolved as a counterfactual to the benchmark. The differences between the benchmark and counterfactual suggest how the simulated economy will shift given some change policy or project. This method for measuring economic impacts has become popular in academic literature as well as among federal government agencies (e.g. the EPA’s EMPAX-CGE), but not necessarily yet among state-level government agencies.

Most uses of CGE models in transportation research involve a multiregional framework that enables explicit modeling of travel costs and specific changes in sub regions (Böhringer and Welsch, 2004; Bröcker, 2000; Buckley, 1992). Such multiregional analysis, however, adds a level of complexity that can create undue confusion. Conrad and Heng (2002) demonstrate that when overall benefits to society are the variable of interest, a multiregional model is unnecessary.

It is important to be aware of some common limitations of CGE models. One of the primary limitations, which has been well documented by Partridge and Rickman (2010), is that CGE models are calibrated to a single year and thus are subject to biases toward the state of the economy in that year. Another potential problem is that CGE models do not handle the introduction of new businesses, exporting opportunities, or importing opportunities well. Similarly, full secession from a certain activity cannot be modeled well with a CGE. For example, if it no longer makes sense for a business to operate in a given scenario, the model will still show it operating but at a very low level.

The most popular alternative model for measuring economic impacts in transportation literature is traditionally the Input-Output (I-O) model, which is one of the oldest models for simulating project impacts and is still used in many recent studies (RESI, 1998; Liu and Vilain, 2004; Giuliano et al., 2011). The I-O model, however, has many well documented liabilities and most peer-reviewed articles dealing with the topic recommend always using CGE over I-O if possible (Seung et al., 1997; Rose and Liao, 2005; Dwyer et al., 2005, 2006; Partridge and Rickman, 2010; Cassey et al., 2011).

Another issue requiring discussion when dealing with regional policy decisions is the difference between economic impacts, as measured through economic impact analysis, and net social welfare. Welfare is touted as the more appropriate metric for decision making (Abelson, 2011; Edwards, 1990); however impact is very widely used. This is not for theoretical reasons, but rather because impacts are more readily understood by a lay audience. An impact can be stated as a change in the number of jobs—a very easy to understand and increasingly demanded performance metric; net social benefits are defined in terms of utility, something only economists tend to discuss. It also could be the case that impacts are so popular due to the long-time dominance of I-O models in regional science. Unmodified I-O models are incapable of estimating net social benefits, leaving impacts as the only available metric.

CGE models, on the other hand, can be used to directly estimate social welfare, generally by calculating equivalent variation (Hirte, 1998; Böhringer and Welsch, 2004; Nam et al., 2010). Alternatively, Dwyer and Forysth (2009) explain that Benefit-Cost Analysis (BCA) and Economic Impact Analysis (EIA) can be married by subtracting the costs of factors of production from the impact of an event (as calculated in a CGE model) and adding the remainder to the other surpluses calculated through BCA to generate a robust, general equilibrium cost-benefit ratio. While this seems somewhat round-about given that CGE models can directly estimate welfare, it is nevertheless effective.

Chapter 4 Methodology

4.1 Economic Viability- Evaluating the Viability Criterion

The economic viability criterion is used to determine whether a particular project will be able to produce enough revenue to cover all of the costs as discussed in chapter 2. In order to evaluate the criterion, the analyst will need to determine or estimate the following values:

1. The annual discount factor (δ)
2. The number of years the facility will likely be in operation (n)
3. The value of salvaging the facility at the end of its useful life (s)
4. The cost of building the facility (f)
5. The cost of using the facility (c)
6. The cost of maintaining the facility (m)
7. The level of demand that will be met by the facility (D)
8. The price of services charged by the facility (p)

For the most part, all but the last two values will depend on the preferences of the organization and/or information obtained from the project proposal. The estimates for demand and price, however, can be independently estimated. Sensitivity analyses can be done to evaluate the impact of missed estimates of the parameter. The remainder of this section examines each of these variables and describes some basic guidelines for evaluating estimates. In particular, a tool and methodology for estimating/projecting demand is presented and the impact of price is discussed.

4.1.1 Discount Factor

The discount factor reflects the lost value of money when it is obtained in the future rather than immediately. If future funds were held today, they could be used for investment and thus accrue interest. The actual discount factor used for viability calculations will then depend on the opportunities for investment that are currently available to the organization. If the interest rate of alternative investments is known, then the discount factor can be calculated as $\delta = \frac{1}{1+r}$ where r is the interest rate. Common interest rates tend to be between 3 and 12 percent—a higher interest rate means a lower value of future returns.

4.1.2 Expected Life and Salvage Value

Both the expected life of the facility and the salvage value will have to be estimated. The expected life can represent either the actual number of years that the facility is expected to be in operation or the number of years relevant to the project and/or decision maker.

4.1.3 Costs

Detailed information on the potential costs of the project will be given in the project proposal. These cost estimates can be potentially verified by comparing them to the costs associated with similar facilities. Such costs are generally unknown to parties outside of the organization that operates a facility, but agencies can conduct surveys in order to elicit some of these data.

As mentioned in the discussion of economic viability in Chapter 2, two important aspects of variable costs should be considered. First, usage/operation costs are likely to exhibit economies of scale. This means that in general, average costs will decrease as more demand is met by a facility. Any accurate estimate of costs should include some estimate of the level of economies of scale associated with the facility. Second, maintenance costs of a facility will likely increase as it ages. Then an accurate estimate of maintenance costs should show increases over time.

4.1.4 Demand and Price

The quantity of transportation demand met by a facility is influenced by several factors, the most important of which are arguably the distance to potential shippers and the price of using the facility. Referring again to the lumber example, we assume that the lumber mills want to move their product as inexpensively as possible. Nearer facilities are attractive options because trucking any good from the place of production to a transport facility or final market place can be expensive. Nevertheless, if the price of using a facility is too high, potential users will choose to ship their goods through other cheaper facilities even if they are further away. Additionally, the value of time is important for many types of shipments. A shipper may optimally choose to drive farther or pay a higher price to use a facility that can process goods faster than others.

4.1.5 Total Shipping Costs

In order to estimate a simple model of the demand for a particular facility, the analyst will need to estimate the total costs associated with using the facility as well as the total costs of using the possible alternative facilities. We assume that each potential shipper will use the facility with the lowest total costs. From the shippers' perspective, the total costs of shipping can be broken down by section, as shown in Figure 4.1.

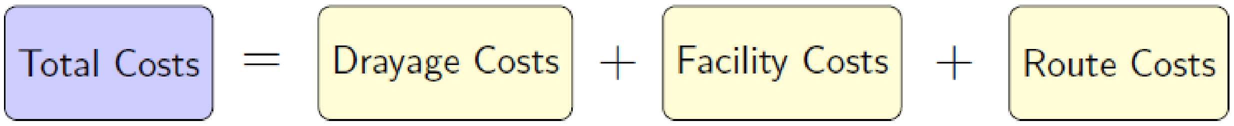


Figure 4.1 Decomposition of Shipping Costs

Here, Drayage Costs are the costs of getting the goods to the facility, Facility Costs are the direct costs of using the facility, and Route Costs are the costs of the shipping the goods from the facility to the final destination. To calculate these costs, we have developed a software tool that uses as inputs the following data:

- The quantities of goods that are likely to use the facility and the locations at which these goods are produced
- The cost per mile per ton of trucking each type of good (Cost/mile/ton)
- The value of time for each good (Cost/hour)
- The locations of all potential alternative facilities, and for each:
  - The rate per ton
  - The processing time per ton
  - The capacity
  - The mode (rail, barge, etc.)

  (Note: these values may also vary by type of good)
- In the case that modes differ between facilities, the cost per mile per ton by mode may also be needed.

For each location of production, the program determines the driving distances and travel times between the location and each of the potential facilities using the GIS routing software. The cost of drayage to the facility is then the sum of the distance cost and the time cost, as shown in Figure 4.2.

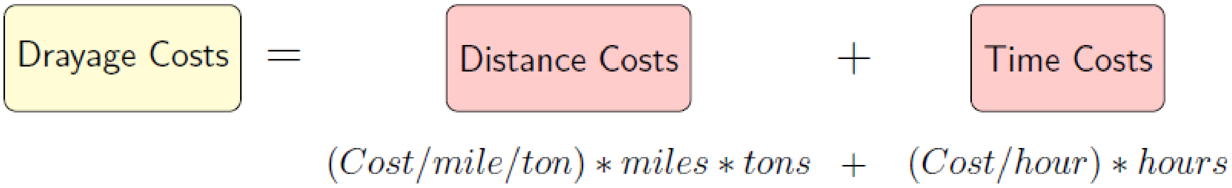


Figure 4.2 Drayage Costs

In a similar manner, we can calculate Facility Costs from the price and time of using the facility as shown in Figure 4.3.

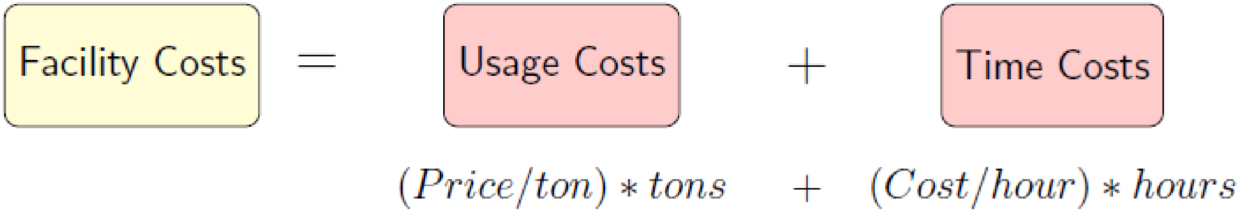


Figure 4.3 Facility Costs

The estimation of Route Costs is a little less straightforward, and depends on the final origin of shipments and on the mode of transportation used. For most shipments in the Pacific Northwest, the final destination is distant enough that differences in the Route Costs are negligible for facilities of the same mode. For example, if the final destination of a shipment from Idaho is overseas or on the East Coast, then the Route Costs will be essentially the same whether one trucks their goods to a facility in Nampa or to a facility in Boise. If, however, the facility in Nampa moves the goods by rail whereas the Boise facility puts the goods on a barge, then Route Costs will differ considerably.

In the case that the choice of facilities includes a choice of modes, then Route Costs must be estimated. This can be done by first identifying the part of the route associated with each of the different modes. For example, it may be the case that whether by rail or by barge a certain shipment is bound for a seaport and then shipped overseas. Then the costs that occur after arriving at the port are essentially equivalent regardless of what mode was used to get there. Then the relevant part of the route is the haul from the facility to the port.

After the relevant parts of the routes are identified, distances and travel times over these sections need to be calculated. Then Route Costs can be estimated by again summing distance costs and time costs as shown in Figure 4.4.

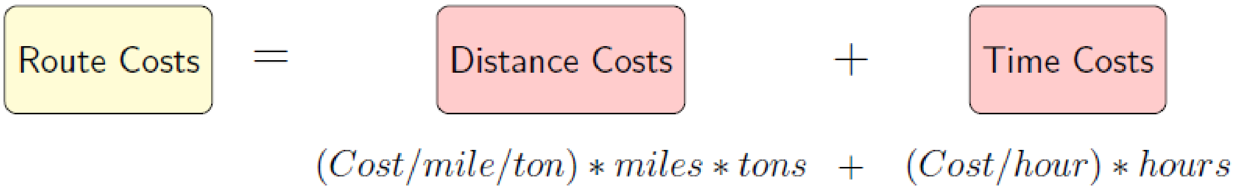


Figure 4.4 Route Costs

4.1.6 Demand

In order to generate an estimate of demand, we can assume that shippers will use the facility associated with the lowest total shipping costs (this will vary for each shipper). The total demand met by any facility is generally the sum of shipments for which the shippers choose to use that facility. If the demand exceeds the capacity of facility, however, then some shippers may be forced to use the option associated with the next lowest total shipping costs. In this case, we must make an assumption about how use of an over-demanded facility is allocated. For convenience, we assume that those who are allowed to use a facility are those closest to the facility (though we recognize that this may not be the case in reality).

4.1.7 Price

Finally, we come to the issue of pricing a new or improved facility. One method to obtain an estimate for price is to use the average price from similar facilities in the region. A more accurate model will allow the owner of the facility to choose a price that maximizes profits, represented by the left-hand side of the Viability Criterion from chapter 2. The program above can be used to generate the demand associated with a given price, and a non-linear solver (which updates the demand for each price iteration) can then find the profit-maximizing price.

4.2 Economic Efficiency- Shocking the CGE Model

After it has been determined that a proposed project (or set of projects) will be economically viable, the next step is to determine the total regional change in social welfare that will occur because of the project. This can be done by first modeling the economy in a computable general equilibrium model (CGE) as it is before the change, and then shocking the model by changing certain variables that will be affected by the project. The model then finds a new equilibrium called the counterfactual, which can be compared to the original condition called the benchmark to produce a measure of Equivalent Variation. After each counterfactual is modeled, the analyst can compare the associated Equivalent Variation values to determine an order of priorities based on which projects will have the greatest positive impact on regional social welfare. The projects with the more negative EV values will have the greatest positive impact on social welfare and should then be given higher priority than projects with less negative EV values.

In a CGE model, every sector of a regional economy must be modeled explicitly. This means that data are needed on production, consumption, and all inter-industry relationships associated with the factors of production (labor and capital) and consumption (earnings and payments). For the case of Idaho and the Pacific Northwest, this is available from the 2010 IMPLAN data. For implementation of a CGE, Social Accounting Matrices (SAMs) representing all economic flows in an economy are generated within IMPLAN and then exported to the Generalized Algebraic Modeling System (GAMS) for modeling.

Professors David Holland, Leroy Stodick and Stephan Devadoss have developed a regional CGE model using the GAMS programming language that has been used extensively, including by this report's authors, for evaluating economic impacts from a host of policy changes. These include applications ranging from statewide economic impacts from mad-cow disease to impacts from tariffs on Canadian softwoods and, more recently, for the legislative mandated "Biofuel Economics and Policy for Washington State" study completed in 2010. For a detailed description of this model, including model closure, specified import demand functions, export supply functions, factor demand functions and household demand functions, please see http://www.agribusiness-mgmt.wsu.edu/Holland_model/ .

The conceptual flow of activities in the CGE is relatively simple and straightforward. All firms in an economy produce their own unique goods from inputs (labor and capital) which are provided by the households. These goods, services and commodities are then either utilized as inputs for other firms or consumed by households at the respective market clearing price. The underlying premise of all CGE models is the assumption that if all markets in a given economy are in equilibrium, then any individual market within that economy will also be in equilibrium and therefore a market clearing price and quantity exists for any individual sector of the economy.

The technical implementation of the GAMS CGE model will not be described here. What follows is a general outline of the process for a given improvement project:

1. Determine the region that is likely to be affected by the project (county, set of counties, or statewide).
2. Generate the SAM for that region using the IMPLAN data and export the SAM for use in the GAMS model.
3. In GAMS, use the CGE model to find the equilibrium price and quantity for each sector associated with the SAM input. This will be the benchmark equilibrium.
4. In GAMS, set the counterfactual statement to reflect all the shocks associated with the project:

    Aggregate costs for shippers (users of the new facility), separated by industry (e.g. agriculture):

    This is represented in the CGE by transfers from the shippers to the transportation sector. The aggregate shock should account both for usage of the new facility as well as the potential decrease in usage at other facilities. (Note: this captures the immediate changes in consumer and producer surplus as described previously and shown in Figure 4.)

    a. Building costs:

    This is represented by transfers from whoever is responsible for building the facility (e.g. the government, or the transportation sector) to the construction sector.

    b. Maintenance Costs:

    This is represented as a transfer from whoever owns the facility (likely the transportation sector) to the services sector.

c. Government Spending:

If the facility is operated in part by the government, requires some subsidy from the government, etc., then a transfer must be made from the government sector. If the funds are coming from the federal government, then this can be modeled as an exogenous influx of funds. If the funds are coming from local governments, however, then local tax rates must increase in order to reflect the fact that such funds are limited.

One thing for analysts to keep in mind is that the CGE model is not a dynamic model, so all changes are assumed to occur at one point in time. For this reason, all transfers (costs and/or revenues) should be measured as annual averages. This is especially salient with respect to building and maintenance costs, the first of which only occurs in the first year with the latter occuring each year but likely increasing over time.

5. In GAMS, use the CGE model to find a new equilibrium that incorporates the above counterfactuals. This will be the counterfactual equilibrium.
6. In GAMS, find the Equivalent Variation (EV) associated with the benchmark and the counterfactual.
7. Repeat this process to generate an EV value for each project.

The end result of this process is an EV value associated with each project. As described above, the projects can then be prioritized by differences in the potential impact on net social welfare. The projects with the most negative EV value represent the greatest increase in social welfare. Especially when funds are limited, it is important for an agency to know which projects should be undertaken first (or in the place of others). Having a meaningful measure of how beneficial each project is to the region is a valuable tool for such prioritization.

4.3 Implementation Data Needs

Implementation of the above two stage models is highly dependent upon the ability of the analyst or agency to satisfactorily compile the necessary data inputs and thus provide meaningful calculations of expected costs, and demand of the facility. While the majority of the transportation links within and around the PNW are sufficiently known or capable of being estimated, significantly less is known about several of the agricultural nodes within the system. For example, the recent Idaho Statewide Freight Study identified a need to catalogue the location, capacity and modal access (e.g. on site rail access) of major grain elevators. Similar cataloguing should be desired for other industries, such as timber, in which multiple modes are utilized and individual mills may have rail loading facilities on site. In addition to facility capacity and utilization itself, the condition and utility of the rail line should be considered for its ability to sufficiently meet current operating practices on the Class I mainlines to which products often ultimately connect.

Such nodal data thus permits the origination of service area development for existing and proposed facilities. Generally, determining service areas for a facility as well as the related flow of resources to facilities depends on a number of factors including assumptions on hauling distances, driving speed limits and truck transportation rates. Methodologies considering linear, straight-line average haul distances from processing locations may neglect local infrastructural factors, such as speed limits, elevation or road curvature that influence total driving times. In contrast, GIS-based models involve geographically referenced datasets that contain relevant geometry and attribute information for the spatial features (e.g. intermodal terminals, roads, etc.).

A fundamental difference between GIS-based and non-GIS models is that datasets in GIS models, such as geographic distribution of production sites, highway networks and terminal locations in the study area can be layered and geographically integrated. The multi-layer datasets allow spatial manipulation of that integrated information, such as extraction of total flow of goods information for a given facility or for a state/county.

4.3.1 Specific Data Needs

- Production Locations and Quantities (e.g., wheat field locations, sugar beet production, freight generating firms)
- Terminal Locations (current and proposed)
- Sale prices at location for product
- Per ton mile transportation costs
- Network shapefiles (transportation networks, and regional boundaries)

4.3.2 Model Structure[2]

The GIS-based model consists of three main parts. Each of which includes several procedures. Part I builds a dataset by layering GIS shapefiles that are necessary for the analysis. Part II involves GIS Network Analyst extension (or TransCAD) procedures for a) creating a shapefile of the service area for each given shipping terminal in the study area, and b) joining and relating this new shapefile with existing GIS layers. Part 3 of the model involves spreadsheet operations to generate further analysis with the GIS-generated spatial data. Such analysis permits the visualization of the availability of the desired commodity or industry production with the catchment area.

4.3.3 Procedures and Processes

The shapefiles developed in Part I include a layer of production locations and quantities, a road network layer, a layer of current and proposed terminal locations, and a base layer of to be determined scale (e.g. zip code, county, state). The production-location shapefile (or other spatially referenced format) represents a geographical layer with attribute information, such as area and boundaries of production locations. For agricultural production, often the most complete and granulated data is the USDA's CropScape data, available in a raster form.[3] Integration with

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[2] Adapted from FPTI Research Report No. 4. *Biomass Inventory Technology and Economics Assessment.* http://ses.wsu.edu/wp-content/uploads/2015/07/FPTI-4.pdf

[3] Resolution of CropScape generates 30 meter pixel units. 1 pixel = 0.222394 acres

the area of analysis shapefile provides availability information for the production of the good by desired geographic unit. ArcGIS's spatial analyst provides sufficient overlay and spatial join operations to sum the production over the spatial unit.

Simultaneously, network data sets may be joined to the GIS road shapefile's attribute table. This procedure assigns travel times to each of the road segments, which in turn enables the calculation of driving distances and times from production locations to terminals. In instances where significant impedance is expected, true travel times will be preferred over stated speed limits of a roadway segment. For each production location, the closest facility and the associated route and driving distance/time are identified. The service area of a facility, then, is constructed by combining all production locations for which the facility is the closest. After the generation of service areas, the total flow of goods through a facility and the associated cost of acquiring those goods can by determined. (Note: This process can also be expanded to determine the distance/time and associated costs of distributing the goods after being processed at the facility; e.g., with the addition of a railway or waterway shapefile for the specific mode associated with the facility.)

In Part III of the model, the data generated by the network analysis in Part II is exported into a spreadsheet to complete the analysis. First, the total amount of a good flowing through each facility can be combined with the market price of that good in order to determine the cost to the facility owner of obtaining the goods. Second, the transportation costs incurred by producers of the goods can be determined by combining the distances to the closest terminal with the per-ton-mile trucking costs. Additionally, if the network analysis includes distribution from terminals to final consumers via railways, waterways, etc., then total distribution costs can be similarly calculated using per-ton-mile costs for the particular mode.

Chapter 5 Attribute Identification for Asset Viability

The previous sections outline the process behind the evaluation of proposed assets from an incremental change or marginal perspective. The utility of such detailed analyses is evident in its ability to identify the economic impact and social welfare impacts of proposed facilities. However, it is reasonable to expect that not every intermodal facility, small loading or unloading facility, or proposed port expansion warrants a full blown impact and welfare analysis. Many such facility evaluations simply require the identification and objective evaluation of the nature of surrounding attributes that may support or inhibit its operation. Where attribute identification suggests strong probability of viability, the impact and social welfare analysis may then be implemented.

Similar to the previous discussion, we focus on the ability of a facility to generate a Return on Investment (ROI) that will maintain business activities and justify continued renovation and reinvestment. Thus, it is the goal of this section to describe the functional relationship between attributes (independent variables) and the dependent variable of economic viability. Many of these dependent variables directly refer back to those costs displayed in Figures 4.2 through 4.4, as well as Equation 1.

Casavant et al. (2004) Identified a set of 13 attributes (independent variables) considered to potentially and directly impact the viability of intermodal centers. Table 5.1 shows those attributes considered by Casavant et al., and are considered with respect to the PNW and neighboring facilities.

Table 5.1 Conceptual Model and Variable Selection

Dependent Variable	Independent Variables
Economic Viability - Profit per Unit -Operational Efficiency	Ownership Type
	Access to Modes
	Capacity
	Distance to/from Supply Markets
	Distance to/from Destination Markets
	Commodity Mix
	Ratio of Transportation Rate to Commodity Value
	Time to Build Degree of Automation
	Labor Availability
	Labor Cost
	Tax/Zoning Incentives
	Available Land/Space

The directional impacts (positive or negative) of the attributes above may be considered for both their relevancy to facility type as well as their degree of influence on viability. For example:

Ownership Type is a qualitative attribute revealing the structure of ownership (public, public/private, joint venture, etc) and the inherent risk and reward associated. Expectation suggests that increased public and private involvement diversifies the risk and reward balance, thus increases the prospects of viability.

Modal Access identifies the ready implementation of an intermodal facility and the capacity to easily connect to mainline operations without the necessary construction of significant new segments. Thus a facility with onsite or nearby access, to say rail, would suggest a higher likelihood of viability than one further away from those resources.

Capacity and *Distance to and from supply and destination markets* are two additional and vital attributes that generate significant influence on viability for most facility types. Capacity may be measured in multiple ways depending on facility type. Such measures include, car-loading potential per unit time, ton processed per year, storage capacity, and track length. Frequently with such facilities, the cost per unit moved is negatively related to the facility size or capacity; frequently referred to as economies of size. Supply market distance or productivity of the local area plays an important role, particularly in relation to the capacity of the facility. Each facility will have a minimum amount of product being processed through it to ensure viability. The distance needed to obtain this volume is the threshold. Similarly, produces and shippers will have a minimum distance they are willing to transport their product based on their transportation cost structures. This distance is known as the range or a product. So long as the range is greater than the threshold, then the prospects for viability are positive. Where threshold exceeds range, viability is significantly hampered.

Consideration of several attributes above are discussed below as they relate to two identified case studies in or near Idaho. Both directly relate to good produced in Idaho and transported on Idaho networks. The first is a newly developed multi-car grain loading facility in neighboring Whitman County, Washington. The new loading facility serves farmers and their cooperatives from both Washington and Idaho. This site was selected due to the readily available elevator storage locations known in Washington State[4], thus allowing estimated market areas for the new and existing sites.

The second case study is based on material submitted for the REDIFiT Gant program for Glenn's Ferry in response to the growing agriculturally based industry in southern Idaho and the existing rail facilities in place. The application submitted identifies Salt Lake City as the current connection point local agriculture users must truck their goods to for rail connection.

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[4] Washington State Department of Agriculture Maintains a Warehouse Audit program that identifies the location and capacity of all commodity warehouses.

Chapter 6 Case Studies

6.1 Multi-Car Gain Loading Facility

The opening of the McCoy multi-car grain loading facility has significantly affected the geographical landscape and direction of the grain flow in southeast Washington and Northern Idaho. Historically, a fine demarcation of modal usage has existed throughout the regions. Figure 6.1 shows the typical breakout of modal usage in the Palouse region. Both have heavily relied upon barge transportation. While the introduction of a single facility does not completely alter the larger movements of the region, it does, on the margin affect the cost of transport of wheat within the service area of the new facility and provide wheat buyers more modal choice.

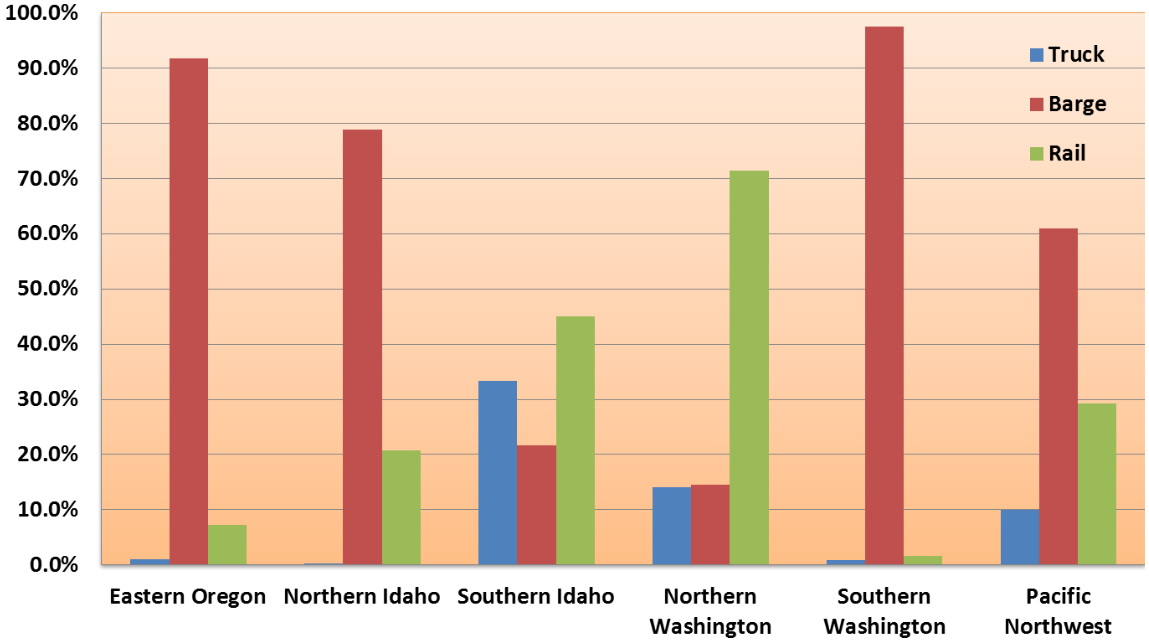


Figure 6.1 Typical Percentage of Wheat Shipped via Various Modes in the Pacific Northwest

The McCoy site began major operations in 2013-2014 and draws from local elevators and on-farm storage as well as serving a storage function for some movements from the Midwest. The McCoy facility lies on the Washington State owned P&L branch of the PCC short lines. Jointly funded by two regional cooperatives, Pacific Northwest Farmers' Cooperative (PNW) and the Cooperative Agricultural Producers (Co-Ag), McCoy provides the combined 1,500 grower members an additional outlet and driver in getting their product on the market effectively.

Using the GIS modelling procedures previously identified, Figure 6.2 demonstrates the catchment areas for grain elevators in Whitman County. These catchments are derived solely from service area designations for least cost (time) roadway transportation to the identified facilities. The catchment area identified for the McCoy facility (blue) through this mechanism appears unusually small given the scale of facility constructed. It would appear at first that the threshold exceeds the range. In fact, using this catchment area strategy, suggests that McCoy would be the facility of choice for farmers on just 5,000 acres, or roughly 325,000 bushels worth. This catchment is approximately ten percent of the available storage in either the elevators or outside temporary storage on site.

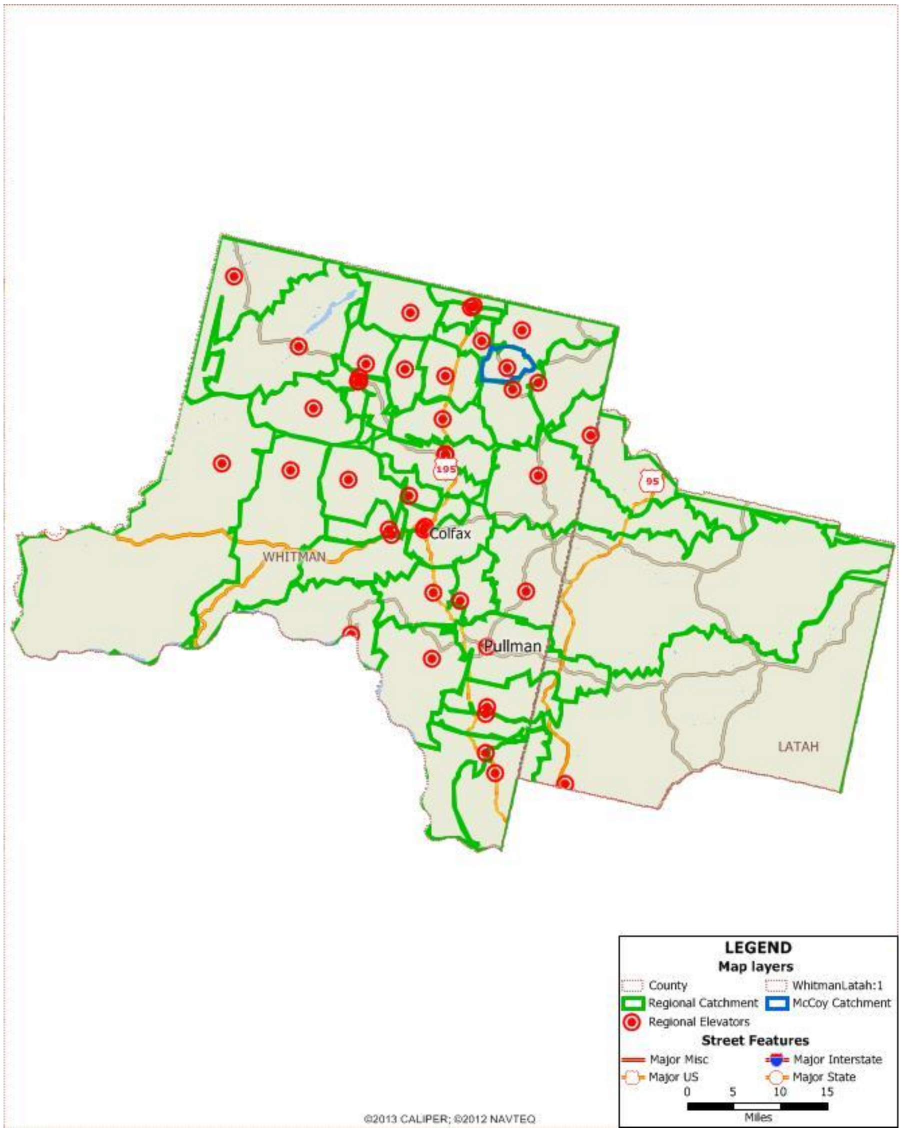
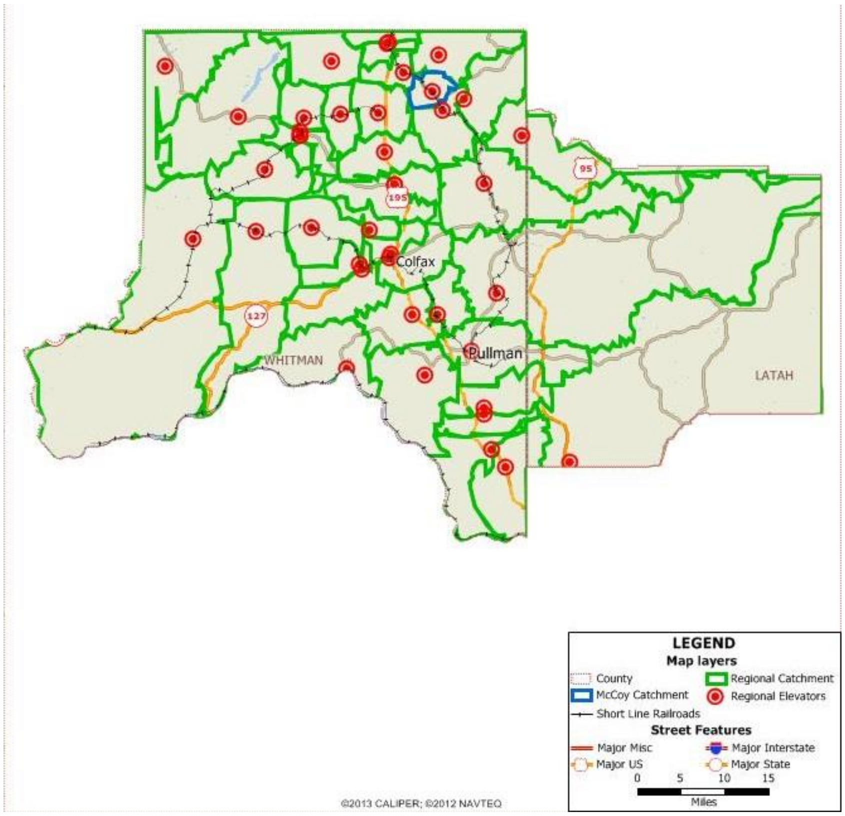


Figure 6.2 Regional Elevator Catchment Areas

Using the attributes in Table 5.1, we can consider the *distance to/from supply markets* to be the available volume in local production area. While the Palouse is some of the highest density wheat producing land in the world, this first glance does not alone suggest it is capitalizing on such production. However, the McCoy facility lies on the P&L line of the PCC railroad and provides a link directly to the BNSF in Marshall, WA. Reexamining the region's elevators (Figure 6.3) and considering now a second attribute, *modal access*, we may consider the catchment of McCoy to expand outward and take increased advantage of the local production area.

In addition to the broadening expansion area, the new facility and loading capabilities strengthens the demand for utilization on the P&L line thus providing larger support and justification for public investment in the rail line asset; creating stronger public/private partnership prospects and benefits. These benefits are generated through increased economic competitiveness of the region's producers and diversion of truck off the roadway. The McCoy facility c contributes to the reduction in roadway miles. The facility's managers estimate that:

- Without the facility, 16.4 million bushels of wheat would be hauled an average of 75 miles from farm storage to Central Ferry. This movement requires nearly 20,000 trucks
- With the facility, truck trips to nearby rail loading facilities increase, therefore the volume shipped by rail from storage to McCoy increases, and the number of trucks to McCoy increases (~25 miles), all acting to reduce total truck miles.



©2013 CALIPER; ©2012 NAVTEQ

Figure 6.3 Regional Elevator Catchment Areas with Rail Access

Addressing the remaining attributes (Table 6.1), the nature of the wheat market in northern Idaho and southeastern Washington effectively necessitates the utilization of rail and/or barge movements based on the *transportation rates and commodity value*. The location and operating practices of McCoy allows it to utilize both the Puget Sound ports and those reached by the Columbia-Snake system, thus allowing Idaho and Washington farmers increased access and access options to reach *destination markets*. Additionally, the *availability of space/land* at the McCoy site permitted the creation of sufficiently large operations from which 110-cars may be loaded. Such ability is becoming increasingly vital to rail movements as the Class I railroads realize the efficiency gains generated through utilization of unit or shuttle trains. Finally, this facility does not operate in isolation, the efficiencies gained is an allowance enabled via the partnerships established. In addition to the McCoy facility, McCoy LLC or its funding partners also have storage and access at Central Ferry, Almota and Lewis-Clark terminals, thus providing ready access to the barge system. Through these multiple venues, McCoy is able to flexibly reach its destination markets with significant volume capacity at competitive prices.

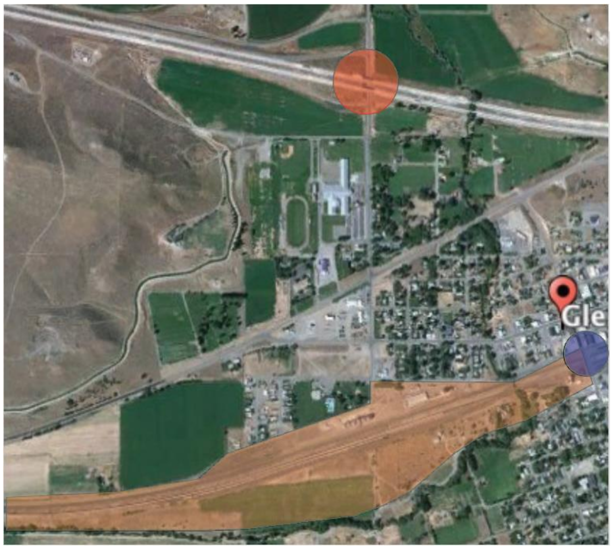
Table 6.1 Variable Importance to Grain Loading Facility

Dependent Variable	Independent Variables	Importance
Economic Viability - Profit per Unit -Operational Efficiency	Ownership Type	B
	Access to Modes	A
	Capacity	B
	Distance to/from Supply Markets	A
	Distance to/from Destination Markets	B
	Commodity Mix	B
	Ratio of Transportation Rate to Commodity Value	A
	Time to Build Degree of Automation	C
	Labor Availability	C
	Labor Cost	C
	Tax/Zoning Incentives	C
	Available Land/Space	A

The evaluation scheme is A = Critical, B = Necessary, C = Contributory

6.2 Glenns Ferry

Glenns Ferry is centrally located along the major southern corridor, I-84, through Idaho. I-84 is Idaho's highest volume freight corridor (Figure 6.4), connecting northwest ports to the rest of the states. The Union Pacific (UP) line connecting the northwest to the rest of the U.S. similarly runs through southern Idaho, roughly parallel to the interstate (Figure 6.5). The proposed Glenns Ferry Rail Yard is located on the UP line and within and around existing rail facilities with significant truck access via a designated truck route as well as land and building availability at two sites within the town.



West Side Facility Area.

Source Glenns Ferry REDIFit Presentation

Despite the rail line presence through the state, significant activity on the line is passing through the state, as opposed to moving Idaho goods. Additional truck freight is suggested to be moving southward into Utah to then be loaded onto the rail system. Community leaders in southern Idaho have suggested these observations arise due to the lack of adequate facilities to provide suitable intermodal services within the state. Even with concerns about rail access in the state, the 2007 Commodity Flow Survey valued the originating goods from Idaho via rail alone topped out at almost $2.2 billion, with an additional $907 million using a rail and truck combination.[5] These originated values represent about eight percent of the total originated freight value from Idaho. On average, these rail shipments are moving over 1,000 miles; these destinations are not typically practical by truck considering the major products moved tend to be cereal grains (1,947 ton-miles), wood products (1,346 ton-miles) and other agricultural and food stuffs (2,113 ton-miles).

East Side Facility Area.

Source Glenns Ferry REDIFit Presentation

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[5] http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/commodity_flow_survey/2007/states/idaho/index.html

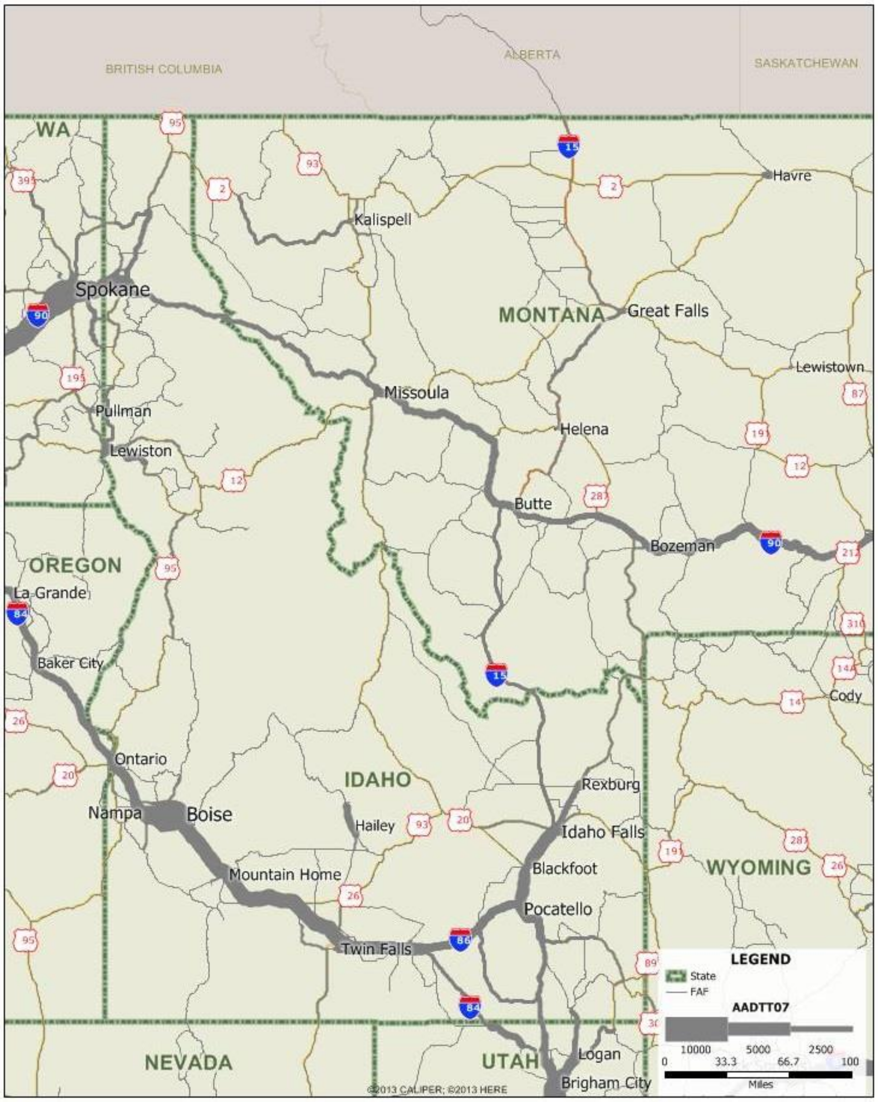


Figure 6.4 FAF3 Based Average Annual Daily Truck Traffic; State Scale

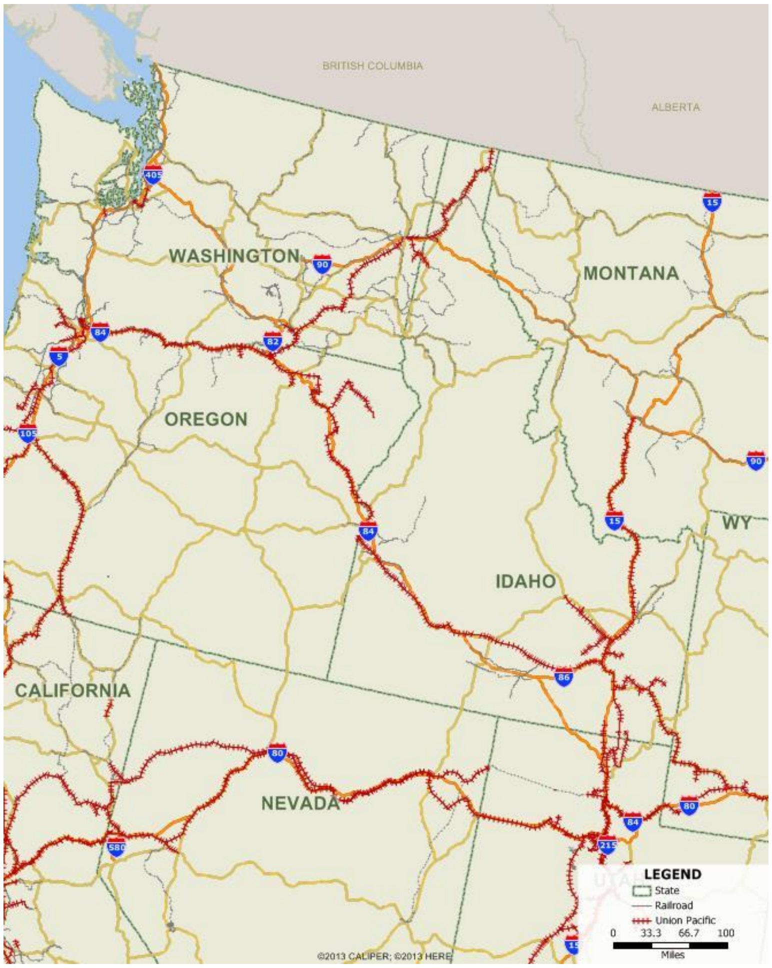
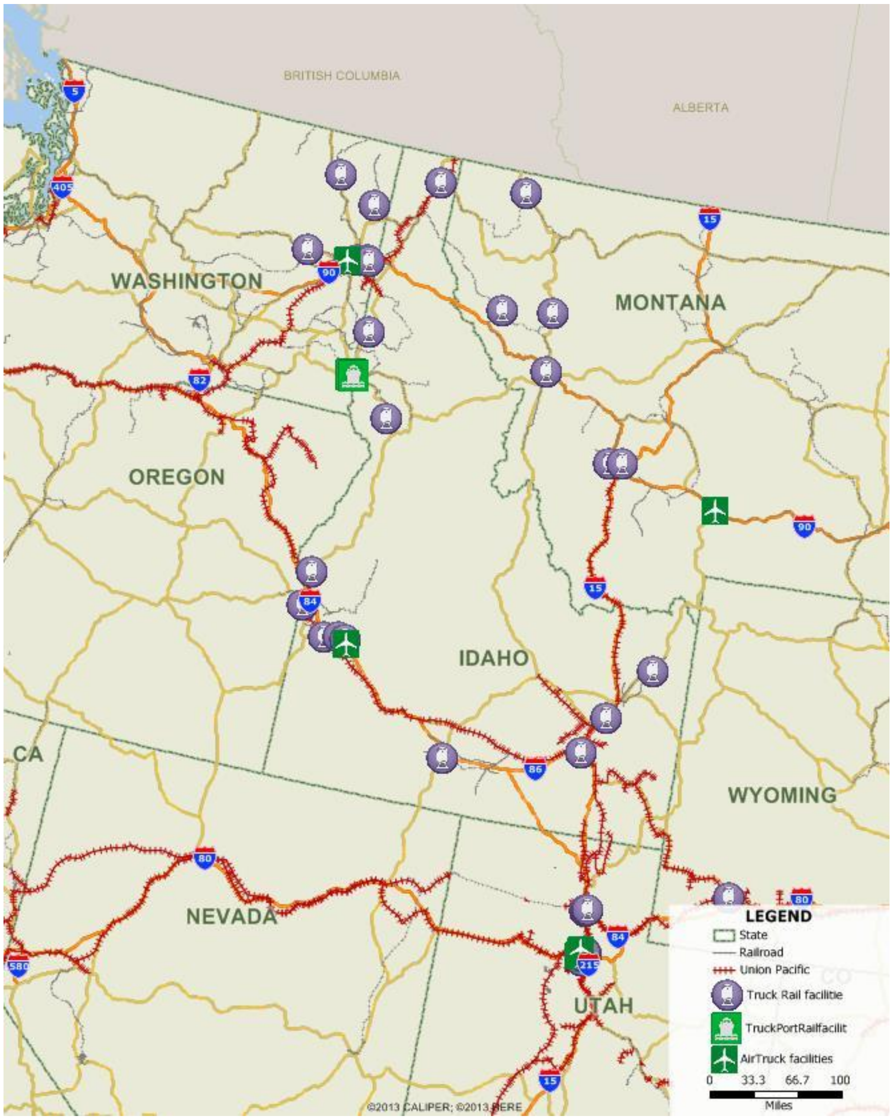


Figure 6.5 Union Pacific Railroad in the Pacific Northwest

A review of the intermodal facilities in and near Idaho lend support to the lack of suitable facilities suggested by regional interests. Figure 6.6 displays all the intermodal facilities found in Idaho and within a 100 mile buffer of the state. In total 54 intermodal facilities were identified within the considered area; 16 of which are located in Idaho (Table 6.2). Roughly half of the Idaho facilities are directly linked to grain production. Not included in the intermodal list are those factories and facilities with onsite rail loading capabilities. Such facilities include lumber mills, as well as some agricultural producers.



Source: 2015 National Transportation Atlas Database.

Figure 6.6 Intermodal Facilities Found in and Near Idaho

Table 6.2 Intermodal Facilities Available in Idaho

Name	Modes Available	City
Boise Airport	Air & Truck	Boise
Bonners Ferry Grain Co.-Bonners Ferry-Id	Rail & Truck	Bonners Ferry
Cargil, Inc.-Lewiston-Id	Rail & Truck	Lewiston
Cld Pacific Grain, Llc	Rail & Truck	Lewiston
Firth Mills-Firth-Id	Rail & Truck	Firth
General Mills, Inc.-Newdale-Id	Rail & Truck	Newdale
Lewiston Grain Growers	Rail & Truck	Cottonwood
Mathews Grain And Storage-Weiser-Id	Rail & Truck	Weiser
Peasley Transfer And Storage Co.-Boise-Id	Rail & Truck	Boise
Port Of Lewiston	Truck - Port - Rail	Lewiston
Potlach Grain And Seed Co.-Potlatch-Id	Rail & Truck	Potlatch
Up-Nampa-Id	Rail & Truck	Nampa
Usps-Amc-Amf-Boise-Id	Air & Truck	Boise
Yellow-Boise-Id Terminal	Rail & Truck	Meridian
Yellow-Pocatello-Id Terminal	Rail & Truck	Pocatello
Yellow-Twin Falls-Id Terminal	Rail & Truck	Twin Falls

Source: 2015 National Transportation Atlas Database.

Based on known freight movement characteristics throughout the region, previous efforts in the greater Boise area have suggested that sufficient rail use demand exists within the southwestern Idaho region[6]. Preliminary efforts conducted to secure feasibility analysis funding by Glenns Ferry have suggested the current flows of agriculturally based businesses (e.g. raw goods, animal feed, food products and others) consists of trucks to the Salt Lake City area for loading to rail cars and further eastward movement. The development and operation of a rail yard facility open

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[6] Greber, B.J.(2012) *REDIFiT Assessment: Boise valley Railroad and City of Boise, Final Report.*

to general freight movement will undoubtedly redirect flows of those trucks from some production areas. The first question that may be asked is what is the catchment area (range) of such a facility. In other words, using Casavant et al.'s (2004) attribute listings, what is the maximum distance from which supply to the facility may be captured. To begin to grasp this distance, we consider the potential service area of a Glenns Ferry based facility in relation to Salt Lake City. Figure 6.7 demonstrates the approximate market boundary between the two facilities. As evident from the figure, all else being equal, a rail loading facility located in Glenns Ferry has the potential to capture freight generated movements throughout much of southern Idaho, potentially as far east as Pocatello. Note that these market areas only include the two discussed facilities. Cold car loading facilities such as RailEx in Wallula Washington currently have market areas of roughly 300 miles and would likely shrink the displayed western edges of the proposed Glenns Ferry facility. As such, the displayed area should be considered a maximum extent. The important component of Figure 23 is the boundary line between Glenns Ferry and Salt Lake City.

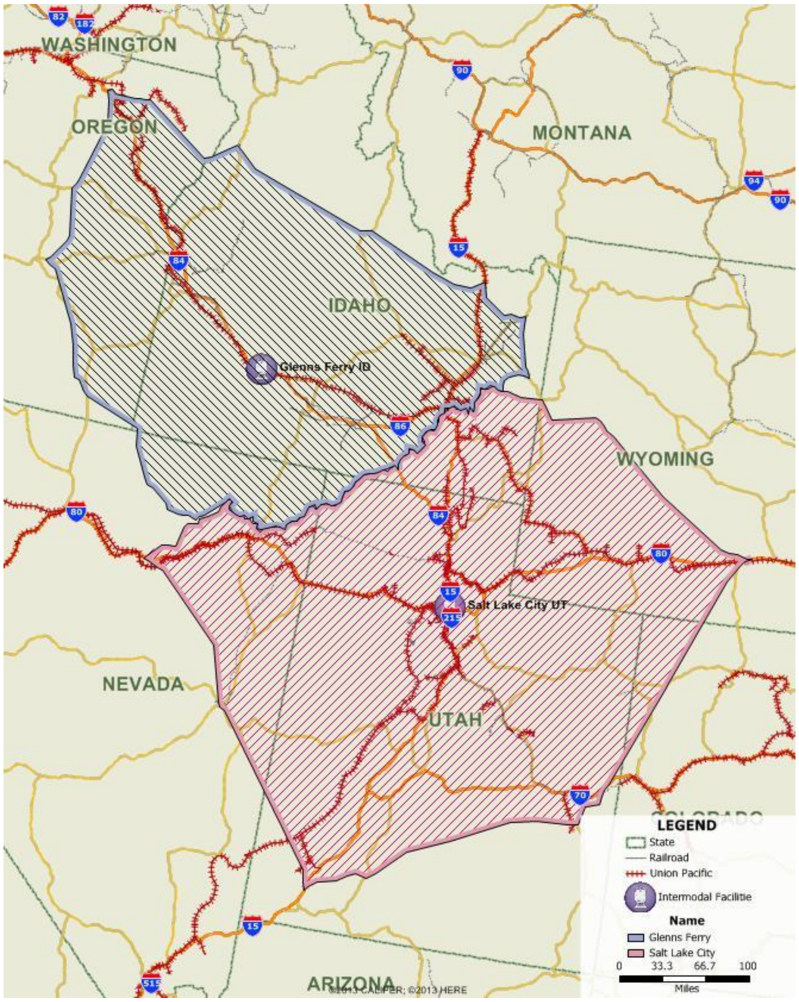

Figure 6.7 Market Area Boundary Between Glenns Ferry and Salt Lake City

The catchment area identified for the proposed Glenns Ferry site encompasses the majority of 24 Idaho Counties. Using the 2012 Zip Code Business Pattern data to reveal the abundance of potential freight generating firms within the regions, we can see that the Glenns Ferry Site finds itself in between two of southern Idaho's major freight generating regions, Boise and Twin Falls (Figure 6.8). This central location begins to suggest a strong opportunity to reduce overall transportation costs for a significant number of freight users in the region.

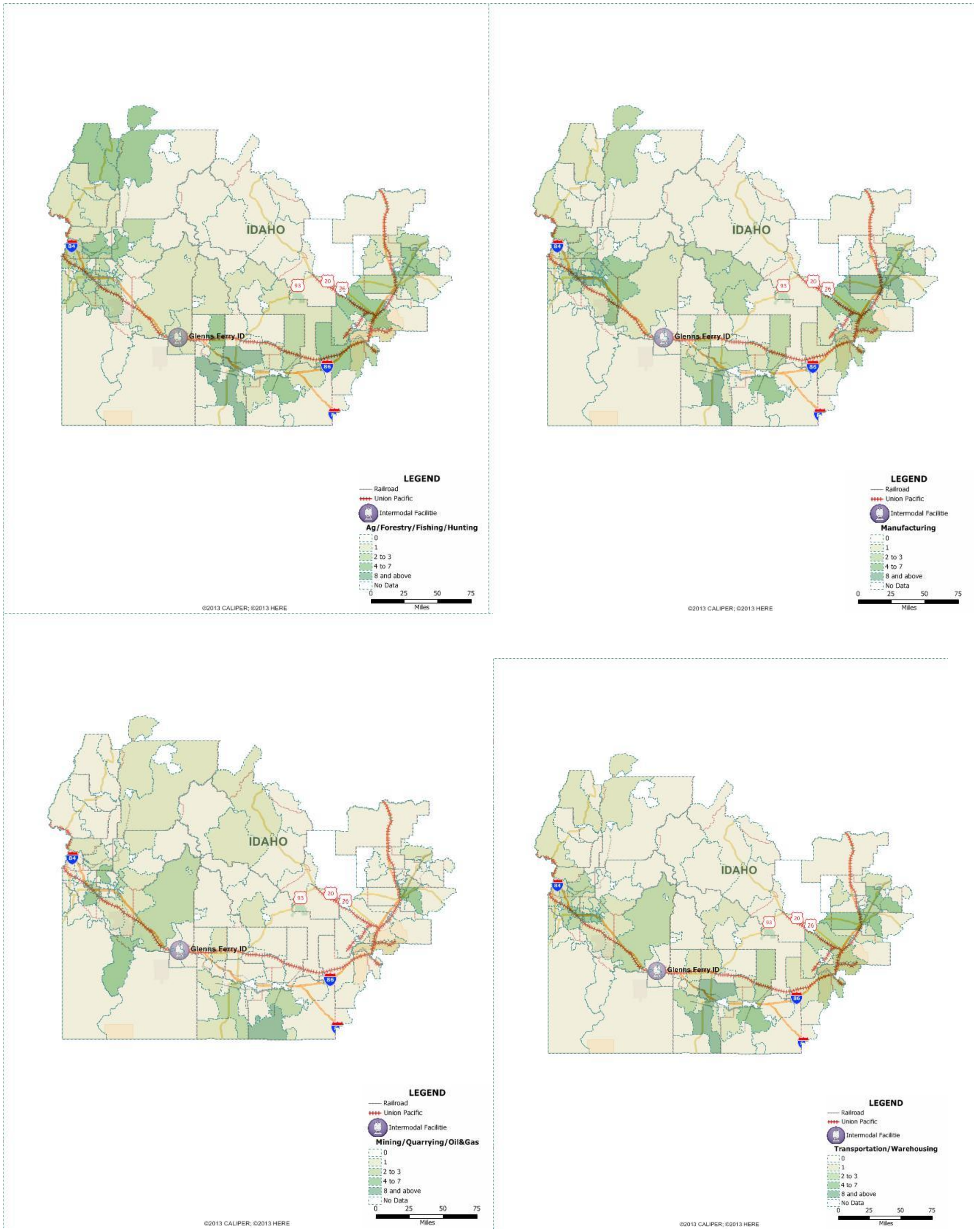

Figure 6.8 Freight Generating Firm Density in Relation to Proposed Glenns Ferry Facility

Summarizing the relationship of an intermodal facility such as that proposed in Glenns Ferry as it relates to the attributes identified by Casavant et al. (2004), we can observe (Table 6.3) that the critical factors to viability are *modal access, capacity, availability of land and space*, and *distance to and from supply markets.* The above discussion has highlighted each of these critical components with the exception of capacity and find that based on the preliminary assessment, a full impact and social welfare assessment should be warranted.

Lessons learned from other rail loading facilities suggest the importance of the ability to assemble and load unit or shuttle trains (capacity). Using two loading facilities in Washington State as an example, from a strictly functional standpoint, where *Railex* has succeeded and the *Cold Train* did not, is largely in their ability to meet the changing needs of the mainline rail system. The mainline system is trending towards unit trains as demand for the line's capacity increases. Thus the ability of facilities to reliably deliver goods to their market destination has become dependent upon their ability to generate sufficient cars. *Railex* could accommodate, while *Cold Train* could not. *Cold Train* has subsequently gone out of business, largely suffering from increased lack of reliability in on-time cars delivered for loading and movement out of Quincy to the Midwest. While it does not appear that refrigerated movement would make up the majority of loadings at Glenns Ferry, there may be some market for such and reliability becomes a paramount consideration, thus ability to meet the Class I needs does so as well.

Table 6.3 Variable Importance to Glenns Ferry Rail Facility

Dependent Variable	Independent Variables	Importance
Economic Viability - Profit per Unit -Operational Efficiency	Ownership Type	B
	Access to Modes	A
	Capacity	A
	Distance to/from Supply Markets	A
	Distance to/from Destination Markets	B
	Commodity Mix	B
	Ratio of Transportation Rate to Commodity Value	B
	Time to Build Degree of Automation	C
	Labor Availability	C
	Labor Cost	C
	Tax/Zoning Incentives	B
	Available Land/Space	A

The evaluation scheme is A = Critical, B = Necessary, C = Contributory

6.3 Temperature Controlled Cargo Loading

As of November of 2013, Washington-based producers of apples, pears, potatoes, carrots and cherries (among numerous others) were moving nearly 1,000 containers per month out of the Port of Quincy on the *Cold Train Express*. The *Cold Train*, as it is commonly referred, is an intermodal carrier transporting many Washington goods to Chicago, IL for further distribution about the broad market for Washington's agricultural products. Taking advantage of the reliability and on time percentage in excess of 90 percent found on the *Cold Train*, Washington producers were nearly guaranteed a 3-day transit time to Chicago, a significant boon for an industry whose products are highly perishable. However, as of August 2014, *Cold Train* has indefinitely ceased all movement. The 90 percent on time performance had drastically dropped to 5 percent according to *Cold Train* executives. A 5 percent on-time rate and an expected transit time of nearly six days cost Cold Train much of its perishable business. Producers were forced to find another, more reliable and potentially more costly mode to transport their 1,000 containers a month – via trucks.

While other refrigerated transport carriers remain confident in their continued performance and successful operations, lessons should be learned in the demise of *Cold Train. Railex,* one of the confidently operating carriers, attributes its continued success to its unit train operation. Unit trains are able to operate without the delays of intermittently adding and removing cars along the route. In recent years, the unit train has been exploding in popularity on Class I lines (e.g. BNSF) because the operations can run more efficiently and at a lower net cost. Unit train operation effectively increases the operating capacity of a line without increasing the infrastructure needs on the line. Non-unit trains, such as those utilized by *Cold Train,* consist of wagonload freight on a consignment basis.

In addition to cold chain movement of fresh goods, the *Railex* facility in Wallula recently opened a 5 million case wine storage facility on its site that is also able to directly load cold cars. This facility serves as a major distribution center for the *Chateau Ste. Michelle* winery. The distribution centers, both the new wine facility and the main loading center, take advantage of the efficiencies offered by both rail and truck, using it for both inbound and outbound freight. The main cold store facility can load 19 rail cars at a time. So what attribute has put *Railex* on the right track?

Railroad Access: *Railex* lies directly on a Class I rail line (Union Pacific). Their ability to provide unit trains (typically 50-60 cars) directly on to the rail is a major contributor to success. The *Railex* facility has ample track on site to effectively prepare its trains for connection to the mainline (Figure 6.9).

Figure 6.9 Aerial View of Railex Facility in Wallula, WA. Loop Track Allows 19 Cars to Enter the Building on the Left for Loading. Photo from Google maps

Major Production Points: *Railex* lies within the heart of Washington's major agricultural zone. The efficiencies in travel and guaranteed temperature control allow the facility to ship produce from within a 350 mile radius to Chicago and beyond.

Major Interstate or Freight Corridor: In addition to lying on a Class I rail line, Railex is able to take advantage of lying on a major highway connection route within the region, thus enabling it to take advantage of the collection efficiencies offered by truck freight.

Commodity Mix: Agriculture is inherently seasonal, thus the ability to handle multiple commodities is a necessary component of a cold storage distribution center.

From a strictly functional standpoint, where *Railex* has succeeded and the *Cold Train* did not is largely in its ability to meet the changing needs of the mainline rail system, trending towards unit trains as demand for the capacity increases, and thus its ability to reliably deliver goods to their market destination.

In sum, the potential viability of a regional loading facility lies in its ability to generate the volume necessary to supply markets at a rate competitive or better than the existing infrastructure. While the attributes of such a facility may vary with purpose, several attributes stand independently of a facility's purpose. These are rated in Table 6.4

Table 6.4 Variable Importance to a Cold Train Loading Facility

Dependent Variable	Independent Variables	Importance
Economic Viability - Profit per Unit -Operational Efficiency	Ownership Type	B
	Access to Modes	A
	Capacity	B
	Distance to/from Supply Markets	A
	Distance to/from Destination Markets	B
	Commodity Mix	A
	Ratio of Transportation Rate to Commodity Value	A
	Time to Build Degree of Automation	C
	Labor Availability	C
	Labor Cost	C
	Tax/Zoning Incentives	C
	Available Land/Space	A

The evaluation scheme is A = Critical, B = Necessary, C = Contributory

6.4 Characteristics of Truck Crashes and the Economic Cost of Crashes involving Trucks-The State of Idaho

For the purposes of this crash analysis, trucks include truck tractors, tractor-trailer combinations, trucks with more than two axles, trucks with more than two tires per axle, or trucks exceeding 10,000 pounds gross vehicle weight. This category also includes pickups with dual rear wheels and smaller vehicles that are carrying hazardous materials. The results presented here are based on the 2014 Idaho Traffic Crashes report compiled by the Idaho Transportation Department (ITD) Office of Highway Safety.

Table 6.5 lists truck crash rates and table 6.6 presents the location of truck crashes by roadway type and severity level. The data show that, while 49% of all crashes occurred on rural roadways, 86% of fatal truck crashes took place on rural roadways. The largest percentage of all truck crashes (50%) occurred on local roads, while the largest percentage of fatal truck crashes (68%) took place on US and State highways.

Table 6.6 shows the number of crashes by severity that each type of commercial motor vehicle was involved in for 2010 to 2014 and Table 6.7 shows different vehicle types as a percent of all vehicles in crashes excluding pedestrians, bicyclists, and non-motor vehicles.

Table 6.8 presents injury severity comparisons by vehicle type for all persons in truck crashes. In 2014, there were 4,574 people involved in truck crashes. Occupants of passenger vehicles comprised 49% of the people involved in truck crashes. Of the 25 fatalities that occurred in CMV crashes, 64% were occupants of passenger cars, pickups, vans, or other vehicles while 28% were occupants of trucks. In 2014, the economic cost of crashes involving commercial motor vehicles was $255 million dollars. This represents 10% of the total cost of Idaho crashes.

Table 6.5 Truck Crash Rates

	2010	**2011**	**2012**	**2013**	**2014**	**Change 2013-2014**	**Avg. Change 2010-2013**
Fatal Crashes	14	22	14	33	22	-33.3%	52.2%
Injury Crashes	378	421	447	495	539	8.9%	9.4%
Total Crashes	1,433	1,535	1,521	1,681	1,613	-4.0%	5.6%
Commercial VMT (100 millions)	27.2	26.9	27.4	28.2	28.6	1.4%	1.2%
Fatal Crash Rate	0.5	0.8	0.5	1.2	0.8	-34.2%	50.2%
Injury Crash Rate	13.9	15.6	16.3	17.6	18.9	7.4%	8.2%
Total Crash Rate	52.6	57.0	55.5	59.6	56.4	-5.4%	4.4%

Table 6.6 Location of CMV Crashes by Roadway Type

	Fatal		**Injury**		**Property Damage**		**All Crashes**	
Interstate								
Urban	0	0.0%	69	12.8%	54	5.1%	123	7.6%
Rural	3	13.6%	82	15.2%	89	8.5%	174	10.8%
U.S. or State Highway								
Urban	2	9.1%	64	11.9%	120	11.4%	186	11.5%
Rural	13	59.1%	102	18.9%	215	20.4%	330	20.5%
Local								
Urban	1	4.5%	124	23.0%	393	37.4%	518	32.1%
Rural	3	13.6%	98	18.2%	181	17.2%	282	17.5%
Total	**22** **1.4%**		**539** **33.4%**		**1,052** **65.2%**		**1,613**	

Table 6.7 Truck Crashes by Vehicle Type

	2010	2011	2012	2013	2014	Change 2013-2014	Avg. Change 2010-2013
Single Unit Truck							
Fatal Crashes	3	8	3	7	5	-28.6%	79.2%
Injury Crashes	119	116	120	119	148	24.4%	0.0%
Property Damage Crashes	319	291	237	266	293	10.2%	-5.0%
Single Unit Truck with Trailer							
Fatal Crashes	0	0	0	2	3	50.0%	33.3%
Injury Crashes	20	14	12	6	9	50.0%	-31.4%
Property Damage Crashes	69	44	36	32	29	-9.4%	-21.8%
Truck Tractor Only (Bobtail)							
Fatal Crashes	2	0	0	1	0	-100.0%	0.0%
Injury Crashes	9	10	10	9	11	22.2%	0.4%
Property Damage Crashes	13	16	28	21	22	4.8%	24.4%
Semi with Single-Trailer Configurations							
Fatal Crashes	8	8	7	19	12	-36.8%	53.0%
Injury Crashes	158	161	192	213	222	4.2%	10.7%
Property Damage Crashes	492	503	471	512	391	-23.6%	1.5%
Semi with Double-Trailer Configurations							
Fatal Crashes	1	3	3	2	1	-50.0%	55.6%
Injury Crashes	34	31	34	28	32	14.3%	-5.6%
Property Damage Crashes	72	91	78	60	56	-6.7%	-3.7%
Semi with Triple-Trailer Configurations							
Fatal Crashes	0	0	0	1	0	-100.0%	33.3%
Injury Crashes	3	4	2	1	3	200.0%	-22.2%
Property Damage Crashes	5	9	3	7	8	14.3%	48.9%

Table 6.8 Vehicles in All Crashes by Vehicle Type

Vehicle Type	2010	2011	2012	2013	2014	Change 2013-2014	Avg. Change 2010-2013
Passenger Cars	17,918	17,102	17,600	18,355	18,471	0.6%	0.9%
%	46.6%	46.9%	46.7%	46.6%	47.1%	1.1%	0.0%
Pickups, Vans, and Sport Utility Vehicles (SUV's)	18,098	16,474	17,124	18,046	17,901	-0.8%	0.1%
%	47.1%	45.2%	45.5%	45.8%	45.7%	-0.3%	-0.9%
Medium Trucks*	543	478	416	443	501	13.1%	-6.2%
%	1.4%	1.3%	1.1%	1.1%	1.3%	13.6%	-7.0%
Large Trucks**	813	859	863	914	788	-13.8%	4.0%
%	2.1%	2.4%	2.3%	2.3%	2.0%	-13.4%	3.3%
Buses	134	110	89	116	108	-6.9%	-2.2%
%	0.3%	0.3%	0.2%	0.3%	0.3%	-6.5%	-3.5%
Motorcycles	549	500	563	534	523	-2.1%	-0.5%
%	1.4%	1.4%	1.5%	1.4%	1.3%	-1.6%	-1.4%
All Other***	385	963	1,019	982	914	-6.9%	50.8%
%	1.0%	2.6%	2.7%	2.5%	2.3%	-6.5%	52.7%
TOTALS	38,440	36,486	37,674	39,390	39,206	-0.5%	0.9%

Table 6.9 Comparison of Injury Severity for Persons in Commercial Motor Vehicle Crashes

Injury Severity	Commercial Motor Vehicle	Car	Pickup, Van and SUVs*	All Other**	Totals
Fatalities	7	8	8	2	25
% of Fatalities	28.0%	32.0%	32.0%	8.0%	0.5%
Serious Injuries	30	37	35	12	114
% of Serious Injuries	26.3%	32.5%	30.7%	10.5%	2.5%
Visible Injuries	82	70	89	7	248
% of Visible Injuries	33.1%	28.2%	35.9%	2.8%	5.4%
Possible Injuries	120	153	155	8	436
% of Possible Injuries	27.5%	35.1%	35.6%	1.8%	9.5%
Non-Injury	1,997	594	1,132	28	3,751
% of Non- Injury	53.2%	15.8%	30.2%	0.7%	82.0%
Column Totals	2,236	862	1,419	57	4,574
(% OF TOTAL)	48.9%	18.8%	31.0%	1.2%	

6.5 Truck Drivers Survey – Quality of Service on Two-Lane Rural Highways in the Pacific North West Region

6.5.1 Overview

For this part of the analysis, we assessed truck drivers understanding of rural congestion and quality of service at two-lane rural highways in the Pacific Northwest region. A mail-in survey was conducted to assess truck drivers' understanding of and response to several issues that impacts the level of service on two lane rural highways such as the availability of passing lanes, quality of winter maintenance practices, availability of truck stops and rest areas, quality of intersections in small and medium size cities to handle truck traffic operations, and overall signage and maintenance practices.

6.5.2 Methodology

Researchers and students at the University of Idaho conducted the survey. The survey instrument was designed using preliminary data collected from questionnaires filled out by truck drivers in one-to-one interviews at several truck stops in Idaho, Washington, and Oregon. The survey took, on average, 12 minutes to complete and was approved by the University of Idaho Institutional Review Board.

The survey was either mailed in- or distributed to truck drivers at different major truck stops in Idaho, Washington, and Oregon with a stamped return enveloped. To incentivize truck drivers to return the completed survey, five $50 gift cards were offered. Overall, a total of 2,300 surveys were distributed, 219 truck drivers completed the survey with an overall response rate of 9.52%. The survey tool is presented in Appendix A of this report

6.5.3 Results

The results of survey questions are presented in Table 6.10. The results show, in general, a higher level of satisfaction with the availability of truck rest areas, snow removal operations, and quality of signage and warning signs. The quality of intersections on cities along the two-lane rural highways and the availability of enough passage lanes to allow truck to pass slow moving vehicles seem to be a major concern for truck drivers. When asked for suggestions for improvements the following items were identified by the majority of respondents:

- Improve weigh-in-motion operations to minimize wait time at truck scales (52.17%)
- Upgrade intersections on the routes to make it easier for truck to turn at intersections (45.18%)
- Better and faster response to incidents (42.89%)
- Expand shoulder driving when possible (40.73%)
- Provide better information about truck stops and diesel stations along the highways (39.18%)
- Educate public about tailgating (18.32%)

Table 6.10 Truck Driver’s Summary Survey Results

	Question	State	Truck Drivers' Response (Percentage)				
			Excellent	Very good	Adequate	Poor	Very Poor
1	The availability of adequate length truck passing/climbing lanes on two-lane rural highways	Alaska	8.33	10.19	43.06	34.72	3.70
		Idaho	2.31	12.04	40.74	37.04	5.09
		Oregon	5.09	13.43	46.30	30.09	2.78
		Washington	6.02	8.33	47.22	32.41	2.78
2	The availability of adequate places to chain-up during snow and ice conditions on two-lane rural highways	Alaska	13.89	25.46	29.17	25.00	4.63
		Idaho	10.19	20.37	35.65	27.78	4.63
		Oregon	25.46	29.17	24.54	13.89	6.02
		Washington	18.06	26.85	33.80	13.89	5.56
3	The quality of snow removal and de-icing on two-lane rural highways	Alaska	15.28	24.07	26.85	25.00	4.63
		Idaho	15.28	27.31	27.78	24.54	4.17
		Oregon	25.46	29.17	24.54	13.89	6.02
		Washington	19.44	29.17	27.78	13.89	5.56
4	The availability of sufficient truck stops or rest areas on two-lane rural highways	Alaska	25.46	24.07	26.85	13.89	4.63
		Idaho	24.54	27.31	27.78	8.80	4.63
		Oregon	27.78	29.17	18.52	13.89	6.02
		Washington	20.83	29.17	27.78	9.26	3.70
5	Intersections’ quality to accommodate trucks in cities along the two-lane rural highway	Alaska	5.09	13.43	40.74	37.04	3.70
		Idaho	5.09	9.26	40.74	37.04	5.09
		Oregon	6.02	9.26	46.30	30.09	2.78
		Washington	6.94	10.65	47.22	32.41	2.78
6	Quality of traffic signs, warning signs, and information boards on two-lane rural highways	Alaska	20.83	28.70	26.85	13.89	4.63
		Idaho	19.91	31.94	27.78	8.80	4.63
		Oregon	23.15	33.80	18.52	13.89	6.02
		Washington	16.20	33.80	27.78	9.26	3.70

Chapter 7 Conclusion and Discussion

As the gateways to an increasingly global market, transportation corridors are the arteries through which all domestic consumption and production flows. Transportation networks stimulate and support trillions of dollars in trade, commerce, and even tourism. In the global economy, they enable specialization in the production of goods and services, which, under the law of comparative advantage, stimulates broader economic growth. Increases in efficiency, if achieved from improved intermodal transportation, aid in that growth. For Idaho to remain competitive in a world marketplace, it must continue to wisely invest in its transportation infrastructure. Federal transportation funding has in recent years begun to demand stricter adherence to a performance based justification for investment. Such performance is often based on the premise of the impact of investment to the region's economic development. Impact's typical measurement comes in the form of jobs and economic output as a result of an increased efficiency in freight mobility as the result of successful balancing of the demand for transportation capacity and service with the quantity supplied of those services and capacities.

To attain this balance requires accurate assessment of transportation demand, and the costs and productivity of transportation services supplied, in order to prioritize the provision of facilities and capacity to achieve efficient freight mobility. This research effort investigated and developed applied methodologies for determining the potential economic viability of intermodal facilities in Idaho. This has been accomplished through two primary mechanisms to evaluate viability. The first is based on incremental (marginal) changes to the network, while the second steps back and provides a tool for preliminary evaluation from a broader scale using a set of attributes deemed important for the vitality of an intermodal facility of many varieties.

Two case studies have been presented here to provide examples of the manner in which the suggested attributes may be evaluated. The attributes lend themselves to a variety of facility types including: truck-rail; truck-truck (distribution center); agricultural collection; truck-port-rail. The attribute evaluation process should be considered a first look at the likelihood of viability. From those facilities that may be considered strong candidates for viability, a more complete marginal analysis should be conducted that implements the two-phased approach defined here. In evaluation of intermodal assets, transportation agencies such as ITD seek to serve not only the industries that may benefit from such an investment, but also the people of Idaho as a whole. As such, identifying both the economic viability of the facility to industry, and the generated social welfare become keys to a complete picture of performance of the proposed facility.

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Appendix A
Truck Driver Survey

This survey is intended to help traffic researchers and engineers understand truck driver's perceptions of certain elements of **two-lane rural highways**. Questions are focused on elements of two-lane highways we think might be of importance to truck drivers and traffic researchers. We would like your answers to be specific to your experiences on two-lane rural highways in the states of **Alaska, Idaho, Oregon, and Washington.**

PART 1 -- The first series of questions asks you to **rate** certain aspects of two-lane rural highways. Please complete the statement by placing a check or X in the appropriate box for each state. Please only give one answer for each state per question.

1. The availability of adequate length truck passing/climbing lanes on two-lane rural highways is…	Excellent	Very good	Adequate	Poor	Very Poor	No Experience
○ Alaska						
○ Idaho						
○ Oregon						
○ Washington						

2. The number of adequate places to chain-up during snow and ice conditions on two-lane rural highways is…	Excellent	Very good	Adequate	Poor	Very Poor	No Experience
○ Alaska						
○ Idaho						
○ Oregon						
○ Washington						

3. The snow removal and de-icing on two-lane rural highways is…	Excellent	Very good	Adequate	Poor	Very Poor	No Experience
○ Alaska						
○ Idaho						
○ Oregon						
○ Washington						

4. The availability of sufficient truck stops or rest areas on two-lane rural highways is…	Excellent	Very good	Adequate	Poor	Very Poor	No Experience
○ Alaska						
○ Idaho						
○ Oregon						
○ Washington						

5. When driving through small towns and communities, the intersections' quality to accommodate trucks is….	Excellent	Very good	Adequate	Poor	Very Poor	No Experience
○ Alaska						
○ Idaho						
○ Oregon						
○ Washington						

6. Traffic signs, warning signs, and information boards on two-lane rural highways are…	Excellent	Very good	Adequate	Poor	Very Poor	No Experience
○ Alaska						
○ Idaho						
○ Oregon						
○ Washington						

PART 2 -- What did we miss? Here is a chance to provide any additional comments or concerns for each state's two-lane rural highway system. Please be specific of your concerns and provide us with some identifiers like highway number, town/area, county, and mile post if you remember. Also provide type of terrain like mountains, rolling hills, or relatively flat.

Alaska
Idaho
Oregon
Washington