CREATING A TRANSPORTATION STRATEGY FOR NORTH DAKOTA EXPORTERS

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

ABSTRACT

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North Dakota's transportation problem is centered on geography and volume. Being a land-locked state and not having an intermodal facility within the economic range of 150 miles from North Dakota production sites, transportation costs severely reduce shipper profit margins. Options available to containerized shippers are limited and expensive.

The purpose of this research is to develop a model that evaluates tradeoffs regarding the development of intermodal shipping capabilities in North Dakota. The following are specific objectives to the research process:

1. Examine historical and current issues pertaining to intermodal transportation in North Dakota.
2. Develop an empirical model to evaluate intermodal pricing, revenues, and demand.
3. Conduct a sensitivity analysis on key random variables and interpret the results.
4. Analyze a variety of coalition cooperative efforts among key players and their effect on North Dakota's transportation environment.
5. Describe a business model that could enable efficient intermodal transportation for North Dakota intermodal operators.

Examining both the base case model and sensitivities applied to the base model allowed for examining today's transportation environment and its potential. The results are reported in chapter five and applied to game theory. Incorporating the results to game theory allows development of a business model focused on subsidizing network operators to cooperate and reposition containers to service North Dakota.

A linear programming model was developed to analyze logistical costs and payoffs associated with varying game alternatives. Data collected was analyzed using GAMS software to determine the cost minimizing solutions for exporters across the eight regions of North Dakota.

Base model results indicate hard IP producers in North Dakota realize minimized costs by draying containers to the intermodal terminals of Saskatoon, Winnipeg, or Minneapolis. Sensitivities were applied to answer "what if" questions related to North Dakota transportation. The first sensitivity test allows for cost of shipping by bulk to the point of export versus required loading of containers at the site of production. Results show that for the three regions encompassing the eastern border and southeast corner of North Dakota (ND4, ND7 and ND8), stuffing containers at the site of production remains the cost minimizing solution.

Sensitivity accounts for hard IP shipments and includes the Minot intermodal terminal. Results show that North Dakota realizes the Minot terminal as an important shipping option. The expanded model and final sensitivity accounts for the 21 metric tons per TEU limitation placed on a containers load weight moving by rail. The addition of this parameter slightly changed model results to reflect a loss of market share to the Minot terminal. Sensitivities were then conducted on the expanded model. These sensitivities display a shift in shipping patterns due to the cost of repositioning empty containers, container stuffing fees, and Minot's terminal handling fee.

ACKNOWLEDGEMENTS

The completion of this thesis is a direct reflection of those who supported my research and education over the past year and a half. I'd like to first thank my advisor and friend, Dr. William Wilson. Working with Dr. Wilson has truly been a privilege. The depth of knowledge and professionalism that I experienced from Dr. Wilson has set a standard of excellence that I will continually strive toward in years to come.

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CHAPTER I. INTRODUCTION

Problem Statement

Important elements of North Dakota's transportation problem are centered on geography and volume. Being a land-locked state and not having an intermodal facility within the economic range of 150 miles from North Dakota production sites, transportation costs severely reduce producer profit margins. North Dakota intermodal operators realize transporting containers to be inefficient and exhausting in today's transportation environment.

Potential investors also consider logistical functions before locating in North Dakota. "Rail access is indispensible," states Dennis Randall, executive vice president and general manager of Schuff Steel's Midwest division Schuff Steel. Schuff Steel Company is a large wind tower manufacturer considering opportunities of locating in North Dakota. Schuff operations would employ 250 to 300 workers over the course of its first three years and would largely impact North Dakota's economy. In his interview with Ryan Schuster of the Prairie Business Magazine, Dennis goes on to say, "It [rail] is an absolute need. We wouldn't consider building a plant at a location without a spur. With the cost of inbound freight...rail service becomes an economic necessity (Schuster, 2010)."

The same is true for North Dakota's intermodal operators. Today, options available to containerized shippers are limited and expensive. Circumstances surrounding container transportation yield two options for North Dakota producers: to interact directly with a containership line to negotiate a shipping rate, or choose to hire a transportation retailer on their behalf. Producers outsourcing the operational details of transportation allow the retailer to oversee inbound and outbound transportation, carrier negotiation, and contracting strategies (Murphy & Wood, 2008).

To reach economies of scale, Class I Railroads are unwilling to commit services to agricultural products requiring short hauls and volumes less than one unit train (Wu & Markham, 2008). The current Intermodal facilities closest to North Dakota are located in Winnipeg, Man; Minneapolis, MN; Regina, Sask.; Chicago, IL; Billings, MT; Butte, MT; and Shelby, MT. Also hindering success to rural producers are the high costs associated with repositioning intermodal equipment. North Dakota's intermodal problem is centered on these limitations and intermodal operators find the limited service to severely reduce profit margins.

For example, a producer of value-added agricultural goods near Minot, ND currently has to incur the opportunity cost and initial drayage fees of acquiring a container from the nearest intermodal facility as well as shipping goods to their final destination. This combination of final transportation modes and the optimal route is determined by evaluating the most cost efficient alternative. Having already narrow profit margins on agricultural goods, additional transportation costs make it difficult for North Dakota to compete in the containerized global markets.

This is further compounded in that North Dakota consists of less than 2% of the Burlington Northern Santa Fe (BNSF) Railway revenue. Due in part to the narrow profit margins on agricultural commodities (North Dakota's greatest export) and volatile shipping needs throughout the year, the BNSF has found it to be more profitable to bypass North Dakota in route to the Pacific North West (PNW).

In recent years, the BNSF has been willing to explore the feasibility of stopping at an intermodal facility in Minot, North Dakota. However, because the BNSF must ensure that profits are not lost in doing so, they have required minimum volumes be shipped out of Minot with each stop. In other words, North Dakota producers need to consistently be meeting specific volume requirements set by the BNSF. Until they do so, the risks associated with shipping demand faced by the BNSF outweigh the benefits of stopping in North Dakota.

The goal of this research was to simultaneously consider the fleet management organization for both rail flat cars needed for operation (transport unit) and the number containers to correspond (load unit). This task presents a challenge in attempting to forecast the randomness of demand and the return of containers and flat cars from customers and railways (Crainic & Kim, 2005).

Intermodal Competition

North Dakota is considered a captive shipping market due to intramodal and intermodal competition being limited within the state (Koo, Tolliver, & Bitzan, 1993). Captive shippers are defined as "shippers located in markets which are dominated by one railroad company and where no alternative modes of transportation are available" (Miljkovic, 2001, p. 299). The distance from eastern North Dakota production sites to Minneapolis is at least 250 miles whereas the distance from Minot, North Dakota to the Pacific Northwest (PNW) is roughly 1,200 miles. Thus, shipping to major markets of consumption, processing, and export suggest that few limits are placed on transportation rates. Due to the lack of competition among Class I Railroads in North Dakota, rates are determined in an imperfectly competitive market.

Economies of haul, across substantial distances, are realized through utilizing both rail and water transportation, because the high fixed costs are spread out over a greater distance. As seen in Figure 1.1, the initial costs for haul by truck (T') are lower than Rail (R') and Water (W') transportation. However, it is important that the slope of transportation costs via truck increases at a higher rate than other modes. The trucking industry is unable to compete for shipping across long distances since the rate of increase is substantially higher when compared to rail or water transportation. Economies of haul by truck are only realized across short distances whereas economies of haul for rail and water transportation are realized across longer distances (Koo, Tolliver, & Bitzan, 1993). A truly efficient transportation system utilizes a combination of these transportation modes and is made possible through intermodal.

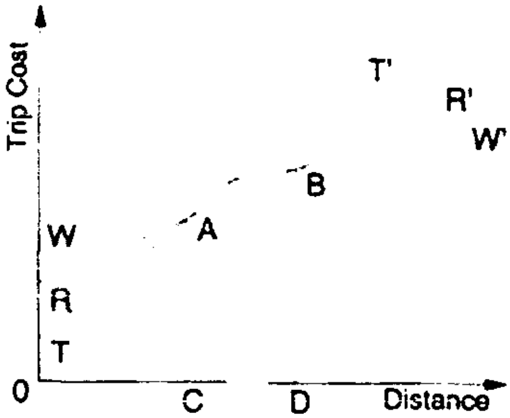

Figure 1.1 Economies of haul given origin/destination

Adapted from Won W. Koo, Denver D. Tolliver and John D. Bitzan, "Railroad Pricing in Captive Markets: An Empirical Study of North Dakota Grain Rates," Logistics and Transportation Review 29, 2, (June 1993): 126.

Intermodal Demand

Containers have created standardization among the shipping industry. Prior to using containers for export, goods were loaded onto ocean vessels by pallet. Loading vessels with goods of various shapes and sizes created a cumbersome and inefficient transshipment process. "Building pallets and loading them into the holds of ships was a slow and labor-intensive process, and the cargoes were vulnerable to damage and theft (Canada and the World, 2008)." Invention of the container increased intermodal port handling efficiencies and quickly became a routine shipping method globally.

The container has revolutionized export markets and the world economy as a whole. Table 1.1 displays the growth in global container traffic from 1993 to 2005. Over the period of twelve years, global container traffic exceeds twice its original volume and continues to increase annually.

Table 1.1 World container traffic

Year	Container Traffic (Millions TEU)	Growth Rate (%)
1993	113.2	12.5
1995	137.2	9.8
1997	153.5	4.2
1999	203.2	10
2000	225.3	10.9
2001	231.6	2.8
2002	240.6	3.9
2003	254.6	5.8
2004	280.0	10.6
2005	304.0	8.6

Adapted from Teodor Gabriel Crainic and Kap Hwan Kim, "Intermodal Transportation," (December 2005): 5.

Significant growth in demand for containers has also grown in the agricultural industry as well. Foods, feed, and beverages represented $108.4 billion of U.S. exports in 2008, and were the second largest export growth category (end-use) for the U.S

(International Trade Administration, 2009). In 2008, three of North Dakota's most prominent products led U.S. export growth; soybeans (up $5.6 billion), corn (up $3.4 billion), and wheat (up $3.0 billion).

Table 1.2 outlines the national rankings and total value of North Dakota's top five export commodities as reported by the United States Department of Agriculture (USDA).

Table 1.2 North Dakota's top five agriculture export estimates for 2008

Export Commodity	Rank among States	Value in Million $
1. Wheat and products	2	1,663.2
2. Soybeans and products	11	687.8
3. Feed grains and products	10	559.4
4. Feeds and fodders	3	341.8
5. Vegetables and preparations	4	332.6
Overall Rank	8	3,949.5

Adapted from the Economic Research Service (USDA), Sate Fact Sheets: North Dakota

Chapter two discusses the differences between bulk and container shipments. A large percentage of North Dakota's agricultural commodities are shipped by bulk for export. However, recent trends in food safety requirements have created an increase in demand for containerized exports. In addition, the increasing demand for specialty agriculture products (i.e. identity preserved, value-added, and organics), has created a shortage in the supply of empty containers allocated to the Midwest; is also be discussed in Chapter two.

Intermodal Players

North Dakota is home to nearly 400 companies exporting goods and services across the world (NDTO, 2010). Containerized shippers in North Dakota range from agricultural machinery and value-added agricultural goods, to military and aviation equipment. Although containerized shipments are also used for domestic transportation, the focus of this research is centered on exports. When considering intermodal transportation in North Dakota, five key players are identified: intermodal operators, drayage operators, terminal operators, network operators, and nature. Figure 1.2 displays the interdependent flow of operations among intermodal players.

International Intermodal Business Model-Export Shipment

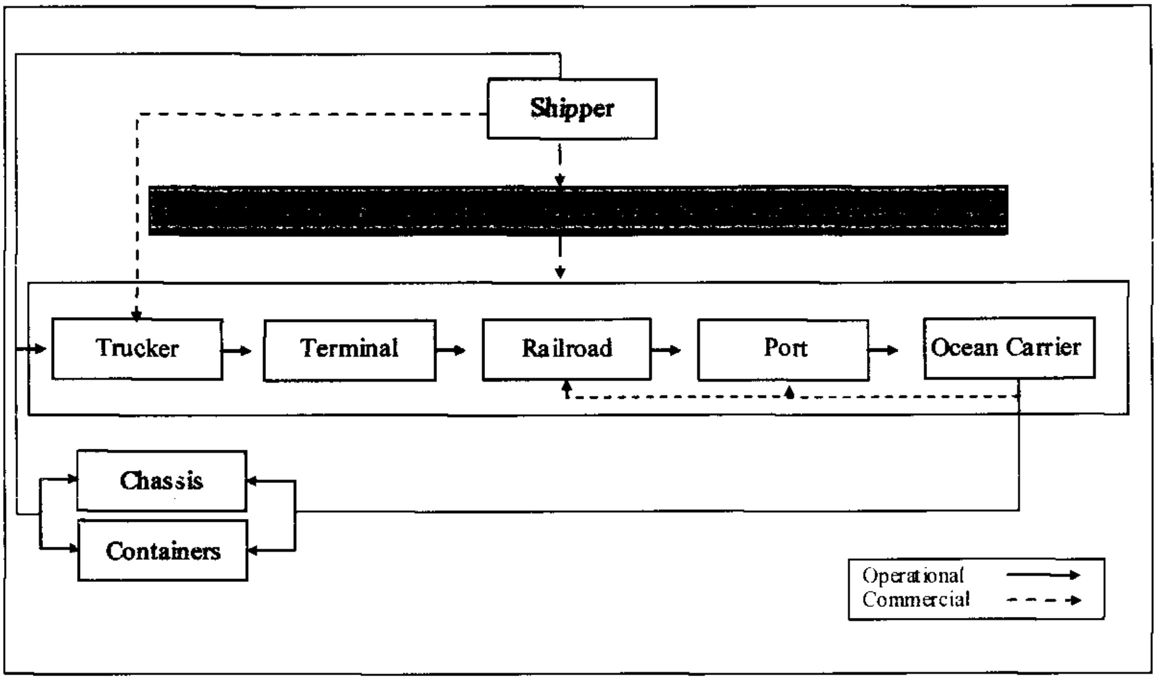

Figure 1.2 International intermodal business model-export shipment

Adapted from Fang Wu and Kurt Markham, "Assessing Feasibility of Intermodal Transport of Agricultural and Related Products on Short Line and Regional Railroads," Minnesota Department of Agriculture (August 2008): 6.

Intermodal Operators

Intermodal operators are considered the users of intermodal transportation infrastructure and services. Producers and shippers possessing goods shipped across two modes of transportation and require sealed containers for transport are categorized as intermodal operators. Intermodal operators in North Dakota include Identity Preserved (IP) grain producers, value-added commodity producers, equipment manufacturers, etc.

Later chapters of this research classify intermodal operators into two categories: Hard IP producers and Soft IP producers. Hard IP producers are defined as producers required to seal containers at the site of production. Soft IP producers however, need only to ship via container for a portion of the transportation chain. This allows soft IP producers the option of shipping bulk to a transloading facility near the ocean port and stuff containers at a location near the point of export.

Drayage Operators

Drayage operators are responsible for organization of the planning and scheduling of trucks between terminals and shippers/receivers (Crainic & Kim, 2005). Intermodal operators having the necessary resources often perform the drayage function in-house rather than outsourcing this function to a transportation retailer. Intermodal operators choose to utilize the services of a third party if lower transportation costs are achieved through outsourcing the drayage function.

Class I Railroads are no longer in the business of marketing intermodal services to the shipper. They have found the role of wholesale service provider to the ocean carriers or third party intermediaries as a more efficient business practice (Wu & Markham, 2008). Third party intermediaries servicing shippers include:

- <u>Transportation brokers:</u> Brokers are an individual or company performing the service of being a liaison between shippers and transportation providers. Many brokers serve multiple shippers and thus quickly gain a depth of knowledge and maintain relationships within the respective industries. Transportation brokers act as independent contractors having a business built on managing relationships.

- Freight forwarders: Freight forwarders are again an individual or company that accepts less-than-truckload or less-than-carload shipments and consolidates them into lots on a for-hire basis (Muller, 1999). Other services provided by freight forwarders include warehousing, preparation of necessary transportation documents, customs clearance for international shipments, and making payment to carriers.
- Intermodal marketing companies (IMC): IMC's offer a "packaged" transportation option to shippers by purchasing individual services from drayage and network operators (i.e. railroad and/or ocean carrier) on the basis of a volume. Once all necessary modes are aligned the IMC then resells the transportation services as a door-to-door transportation package.
- Third party logistics providers (3PL): 3PL's serve as consulting firms assisting intermodal operators manage their supply chain operations. 3PL's unlike other third parties, assume responsibility for the logistics process (Wu & Markham, 2008).

Terminal Operators

Terminal operators are identified as those managing the flow of goods from the intermediary terminal of origin to their final destination along the intermodal process. The operators of ocean ports and intermodal container terminals are considered terminal operators. These key players are responsible for fleet management along the intermodal chain. Their duties include a wide range of planning to create the seamless door-to-door delivery process that defines intermodal.

Duties of a terminal operator might include procurement of power units and vehicles used to transfer goods, vehicle dispatch and scheduling of crews, and continual maintenance operations (Crainic & Kim, 2005). Netland and Spjelkavik (2009) place great significance on the role of this key player by stating, "the [intermodal] terminal is the key to achieve competitiveness in intermodal networks."

Destination terminal operators, or ports, serving ocean carriers can be categorized into three types: on-dock, near-dock, and inland port operators (Wu & Markham, 2008). On-dock operators provide the convenience and safety mechanism of having a rail to ship transfer facility. This ability to transfer containers directly from the rail line to vessel reduces motor carriers on city streets and therefore increases safety to the general public (see Table 1.3). Near-dock operators are located near port terminals and serve multiple ocean carriers. However, unlike the on-dock operator, near-dock operators have increased use of truck transportation and require additional container lifts. Finally, inland port operators are located away from the ocean port terminal. This operator can operate efficiently and avoid the congestion of ports by having a shuttle train connected to the terminal. For inland port operators, the connecting shuttle train largely impacts port profit margins and without it, the inland port will suffer.

Network Operators

Network operators are vital to shippers when considering economies of haul. In the case of this research, the network operators in focus are Class I Railroads (predominately the BNSF and CP rail networks) and ocean carriers. Distances exceeding 300 miles do not allow for drayage rates to compete with those of rail. Table 1.3 emphasizes the importance of network operators by examining the noteworthy trade-offs and opportunity costs associated with container transportation by truck versus rail to the point of export.

Table 1.3 The relative efficiencies and safety of rail and truck transportation

Mode	Fuel Consumption	Infrastructure Capacity	Costs	Safety
Railroad	445 ton-miles per gallon	216 million annual tons per mainline	2.7 cents per ton-mile	0.61 fatalities per billion ton miles; 12.4 non-fatal injuries per billion ton-miles
Truck	105 ton-miles per gallon	37.8 million annual tons per lane	5.0 cents per ton-mile	1.45 fatalities per billion ton-miles; 36.4 injuries per billion ton-miles
Source: Cross Harbor Freight Movement Project Materials prepared by Cambridge Systematics.				

Adapted from Thomas R. Brown and Anthony B. Hatch, "The Value of Rail Intermodal to the U.S. Economy," The Association of American Railroads (2002): 7.

Ocean carriers are one of the industry's most significant players. This is due in part because most often ocean carriers are the owners of leased containers. The numerous actors along the intermodal process operate independently. However, when an intermodal operator goes directly to the carrier for a freight rate for transportation, it is the ocean carriers' duty to align all transportation modes and provide a shipping rate that includes rail and ocean transportation. This rate also includes the handling of goods from intermediary origin location to final destination, with the exception of miscellaneous terminal fees.

Nature

Finally, there are substantial risks incorporated with intermodal shipping. Introducing nature into the model as a player allows this thesis research to capture those sources of risk. For example, North Dakota will need to compete for the surplus of empty containers, and thus, game theory is applied to determine a containers' alternative value.

This value was used to analyze ways in which North Dakota can cooperatively negotiate with containership lines to bring the surplus to North Dakota.

Objectives

The overall purpose of this research is to develop a model to evaluate strategic tradeoffs regarding the development of intermodal shipping capabilities in North Dakota. A transportation strategy involving cooperation among key industry players will be introduced in later chapters. The following are specific objectives to the research process:

1. Examine historical and current issues pertaining to intermodal transportation in North Dakota.
2. Develop an empirical model to evaluate intermodal pricing, revenues, and demand.
3. Conduct a sensitivity analysis on key random variables and interpret the results.
4. Analyze a variety of coalition cooperative efforts among key players and their effect on North Dakota's transportation environment.
5. Describe a business model that could enable efficient intermodal transportation for North Dakota intermodal operators.

Procedure

The feasibility of intermodal shipping in North Dakota is analyzed using game theory methodologies. A prototypical model is being developed to analyze logistical costs and payoffs associated with varying game alternatives. Through game theory methods, a cooperative model is developed to evaluate competitive equilibrium strategies among key players. The problem has five key players: intermodal operators, drayage operators, terminal operators, network operators, and nature. Terminal operators seek to achieve a profit-maximizing price based on individual fixed and marginal costs. After deriving these equilibrium prices for individual players in a competitive strategy, payoffs for individuals in a game operating under a cooperative strategy is analyzed.

The final step in determining the optimal strategy is to compare the payoffs associated with the cooperative game versus the equilibrium payoffs of a competitive game. Under the circumstance in which the coalitions' payoff is greater than that of a competitive game, there is an incentive for key players to participate. However, the opposite is also true: if an individual player can exceed the payoffs of a cooperative coalition by operating independently, the individual will choose not to join the coalition. Many benefits can result from forming a coalition, these include: increased market power, efficient utilization and allocation of combined payoffs, and in the case of North Dakota, cooperative efforts may be the only feasible way to ensure the success of an intermodal facility.

A successful strategy in establishing an intermodal facility keeps in mind the alternative values of containership lines and rail networks to stopping in North Dakota. It is currently more cost effective for network operators to transit through North Dakota with empty containers as it means a quicker turn-around to reposition the empty containers to the export markets of the Asia. Consumer goods imported by North America generate nearly three times the value of agricultural products (Berwick, 2009), creating higher profit margins for both ocean carriers and the rail networks.

For the BNSF, the only way to justify expenses of stopping at a port in North Dakota is for North Dakota to commit to one unit train (220 cars) per turn. Also, if the time costs can be justified, ocean carriers would prefer to have loaded containers picked up in

North Dakota to create a ballast on the return trip to Asia. Greater ballast is achieved through transporting loaded containers rather than repositioning empties to the Asian markets. Ocean vessels, especially the larger vessels (handling 10,000 or more TEUs) require levels of ballast for the ship to sink into to the water and create greater stability while traveling across ocean waters. Transferring loaded containers versus empties has additional advantage to ocean carriers in that repositioning costs are transferred to the Exporter rather than absorbed as a sunk cost.

Hypothesis

This research hypothesized major implications of North Dakota's intermodal industry players joining a coalition to include:

(1) sufficient benefits to be fairly distributed to each signatory member of the coalition;

(2) increased profits as a direct result of operating cooperatively;

(3) minimized risks across the intermodal chain;

(4) and most importantly, the ability for ND intermodal operators to utilize the North Dakota Port Services (NDPS) in Minot, ND as a functioning container terminal.

Organization

The remainder of this thesis is organized into five chapters. Chapter two incorporates background information on the intermodal industry and a review of previous studies. Previous studies included reviewed Economies of terminal operation and the North Dakota intermodal transportation. Chapter three introduces the theory behind the game models developed in Chapters four and five. Chapter four develops an analytical model and provided an explanation of variables and data sources utilized. Chapter five defines the model operations and results. Finally, chapter six provides a summary of the research conclusions and results.

CHAPTER II. BACKGROUND & PREVIOUS STUDIES

Introduction

Chapter II is divided into four parts: 1) defining intermodal transportation; 2) an outline of intermodal functions; 3) past, present, and future dynamics of intermodal transportation in North Dakota; 4) and a brief review of previous studies on the container industry, economies of terminal operation, and studies related to the North Dakota intermodal initiative. For the purpose of this thesis, the freight focus will be centered on "containers of flat-car" (COFC). Other forms of freight such as "trailers on flat-car" (TOFC) will be mentioned but not empirically analyzed by the model developed in later chapters.

Defining Intermodal

In 2001, it was reported that the total value of agriculture exports shipped by container reached 52% (Vachal & Reichert, 2000). Containerized shipping takes place for a number of reasons; buyer request, infrastructure, and quality control are all common reasons for shipping by container. Intermodal transportation can be defined as the movement of goods in a singular loading unit or vehicle which uses successive, various modes of transport without handling of the goods during transfers (Macharis & Bontekoning, 2004).

It is necessary to note that the transportation function "transload" differs from intermodal transportation. Transloading operations include bulk or break bulk commodities that are directly transferred between truck and rail modes using hoses, belts, chutes, pipes, etc, rather than by lifting a container (Wu & Markham, 2008).

The intermodal process begins with the initial drayage of an empty container from its point of origin to the intermodal operators' load site. Loaded containers are then drayed to an intermodal terminal. If the loaded container is shipped by rail, it is often stacked in a waiting pool before being placed on a railcar. Once attached to a transfer unit (i.e. railcar) it then travels the long haul to an assigned port of export. At the port, containers are loaded onto an ocean vessel and delivered to the international port of import to be transferred either by rail or truck to the end-use consumer. Unlike transload shipping methods, the intermodal operator seal of quality is never jeopardized, because the actual product is not tampered along the intermodal chain.

As seen in Figure 2.1, research in the intermodal industry has progressively grown over the past three decades and will continue to spike as consumers and producers recognize the convenience and benefits associated with intermodal transportation.

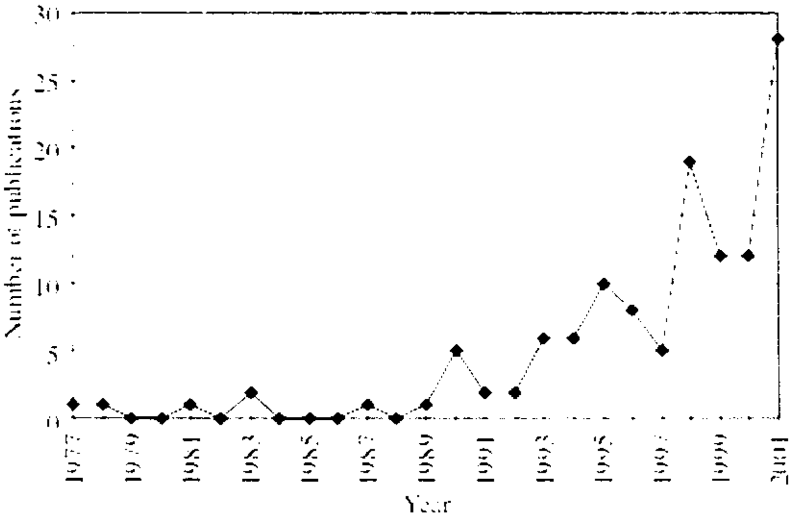

Figure 2.1 The growth of intermodal research

Adapted from Y.M. Bontekoning, C. Macharis, and J.J. Trip, "Is a new applied transportation research field emerging?- A review of intermodal rail-truck freight transport literature," Transportation Research Part A (2004): 7.

The benefits of intermodal transportation include, "lower overall logistics costs, increased economic productivity and efficiency, reduced congestion and burden on over-stressed highway infrastructure, higher returns from public and private infrastructure investments, reduced energy consumption, and increased safety" (Berwick, Bitzan, Chi, & Lofgren, 2002, pp. i-ii). The Association of American Railroads also identified these benefits as they relate to the public sector in a 2008 report (Association of American Railraods, 2008).

Intermodal Functions

The complex nature of the intermodal science can be broken down into several interdependent functions. Table 2.1 provides a detailed outline of these functions throughout the complete process of intermodal transportation. The background previous studies of Chapter two are centered on continental intermodal transportation. Continental transportation involves all forms of transportation prior to the point of export. Maritime intermodal focuses on transportation by ocean vessel from the port of export to the continent of import. For the purpose of this research, road-rail, rail-rail, and terminal operations are the focal points.

In the following sections, the focus of intermodal functions is narrowed into five categories: drayage, rail haul, transshipment, multi-actor chain management, and pricing strategies among transportation modes.

Drayage

The drayage function takes place between a terminal and shippers or receivers (Bontekoning, Macharis, & Trip, 2004). This includes the transportation of an empty container to the shipper-specified location and the subsequent filled container from the shipper to an intermodal terminal.

Table 2.1 Functions of Intermodal Transportations

✓ Provision for public/private infrastructure	✓ Drayage to rail terminal or destination
✓ Marketing and sales	✓ Linehaul to destination terminal
✓ Equipment provision	✓ Drayage to destination from terminal Stripping
✓ Empty delivered to shipper	✓ Drayage of empty container
✓ Container stuffed	✓ Storage of empty container
✓ Documents prepared	✓ Repositioning of empty container
✓ Drayage to rail terminal or port	✓ Matching empty container to demand
✓ Linehaul transportation to port	✓ Operations coordination and contracting
✓ Origin country customs/export declarations	✓ Management and maintenance of equipment pool
✓ Loading onto ships	✓ Invoicing and collection
✓ Ocean transport to destination port	✓ Unload from ships

Adapted from Taylor & Jackson, "Conflict, Power and Evolution in the Intermodal Transportation Industry's Channel of Distribution," Transportation Journal (2000): 6

As seen in figure 2.2, drayage operations indentified by "road haul," are the short-haul trucking portion of the transportation chain, including pre- and end-haulage. Although the drayage function is generally the shortest distance that goods will travel, it is an important and strategic consideration for intermodal operators. Minimizing drayage costs is a key in creating a lean logistics strategy. "Despite relatively short distance of the truck movement compared to the rail or barge haul, drayage accounts for a large percentage (between 25% and 40%) of origin to destination expenses" (Macharis & Bontekoning, 2004, p. 404). High drayage costs can severely affect an producer profit margins and their ability to compete in both domestic and international markets.

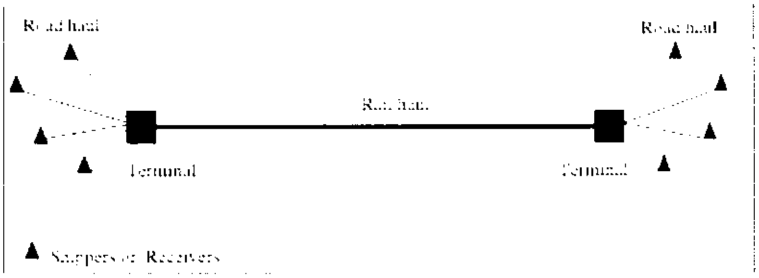

Figure 2.2 Representation of road-rail intermodal functions

Adapted from C. Macharis, and Y.M. Bontekoning, "Opportunities for OR in intermodal freight transport research: A review," European Journal of Operational Research (2004): 401.

Outsourcing the drayage function often results in negotiated rates. The intermodal operator can perform this negation process, or they may alternatively choose to outsource negotiations to a transportation retailer. The business model of transportation retailers is centered on creating and maintaining multiple on-going relationships with drayage and network operators. As such, the transportation retailer can often achieve lower transportation rates than a shipper might otherwise through a single contract. The inland drayage rate fluctuates with input, (i.e. costs the price of fuel), however it is estimated that drayage fees are approximately $2 per mile (Martian, 2010).

Rail Haul

"Rail haul is the terminal-to-terminal segment of the door-to-door intermodal trip" (Bontekoning, Macharis, & Trip, 2004, p. 14). The rail haul portion of the logistics chain involves in-land transportation of goods across distances too great for the trucking industry to compete by economies of haul.

Bulk Vs. Intermodal Rail Shipments

Before the efficiencies of bulk transportation were realized in 1842, grain was loaded in sacks and transferred primarily by water systems. The introduction of bulk grain transportation was appealing to the rail industry because it is able to reduce operating costs and allows for a faster turn-around time of trains.

By the close of the American Civil War, the system of handling grain in North America had been reengineered; making bulk transportation preferred to the system of loading grain into sacks. This reengineering allowed for lower costs to be realized by grain producers from the interior regions of the continent. Lower costs increased trade with interior regions and "opened the settlement of the great plains, and ultimately, the prairies of western Canada" (Prentice, 1998, p. 3).

The advantages of bulk grain shipping have dramatically increased since the late eighteenth century. For example, the modern elevator allows for increased labor productivity and efficiency of loading and unloading grain (Prentice, 1998). For many new to intermodal transportation, it is important to distinguish the differences between traditional (bulk) and intermodal rail shipments. Table 2.2 outlines a few of the key differences between bulk transportation and containerized shipping.

To start, bulk rail shipments run only when all cars are full and shipments are highly classified. Being highly classified simply means that rail operations are centered on the overt knowledge of each shipment's intermediate and final destination. Intermodal shipments have fixed schedules, running regardless of volume. Also, intermodal rail operators are only provided information pertaining to rail terminal origin and destination locations that the goods shipped pass through rather than knowing their origin and destination.

Table 2.2 Tradition vs. intermodal rail shipments

Bulk vs. Container Rail Shipments	
(Bulk)	(Intermodal)
✓ Runs only when full	✓ Runs on fixed schedules
✓ Highly classified origin & destination	✓ No classification of origin and destination
✓ Single variety in shipment vehicle (shuttle car)	✓ Greater complexity in terms of fleet management (i.e. larger variety of shipment vehicles)
✓ Rail yards necessary	✓ Rail-rail transshipment terminals utilized
✓ Many locations	✓ Strategic locations

Adapted from Y.M. Bontekoning, C. Macharis, and J.J. Trip, "Is a new applied transportation research field emerging? A review of intermodal rail-truck freight transport literature," Transportation Research Part A (2004) 1-34.

Intermodal shipments are also more complex in terms of fleet management. Bulk rail shipments operate using a singular variety of equipment (i.e. shuttle car). However, intermodal rail shipments encounter a separation between the transport unit and the load unit; the transport unit being a flat car and the load unit being either a container or trailer (Bontekoning, Macharis, & Trip, 2004).

The large varieties of transport units that encompass intermodal create complexity for fleet management. For example, a double-stack flat car sits lower to the ground to allow for rail passage during shipment and has greater support for holding the containers in place.

The final differences outlined by Table 2.1 between bulk and container shipments are realized through type and location of terminals. Bulk rail shipments require rail yards. Intermodal shipments however, utilize rail-rail transshipment terminals. Bulk shipping has multiple established rail yard locations, whereas intermodal facilities are increasing in number but remain strategically placed and typically spread 750 miles apart (Brown & Hatch, 2002).

Reengineering Transportation

Prentice (1998) makes the argument that just as the system of transportation was reengineered in the late 18th Century to develop the bulk system of transportation, the system is once again needing to be reengineered. Disadvantages realized by the current bulk system of grain handling include a lack quality control, high inventory costs, and empty backhauls. For the seller, a significant difference between bulk and container shipping is that for the bulk system of transportation all operating costs must be paid for by a single commodity. Grain shipments by container allow intermodal operators to pay a marginal shipping cost as the containerized grain is transferred among other shipments containing freight of all kinds.

Prentice (1998) argues five reasons for reengineering the current bulk centered transportation system to better accommodate the needs of an intermodal system. First, Prentice argues that mixed systems are superior to pure systems. Due to seasonal shipping patterns and the costs associated with congestion reduce profit margins. However, using the container system and warehousing goods for a period of time allows shippers to avoid a temporary increase of price.

Second, with the turn of the 19th Century came an increase in production technologies and a larger variety of grains demanded (i.e. IP & organic products). Bulk systems are efficient due to the relatively few number of products they transport. As product varieties are added to the system, economies of scale decline. "The bulk system could operate more efficient if the lower volume, small shipments are moved in containers" (Prentice, 1998, p. 7).

Third, Prentice (1998) argues that, "one size does not fit all." In other words, Prentice is referring to the unique attributes of each product, sales volumes, and customer demands. Products shipped by the bulk handling system are able to compete when selling on price, but find difficulty when selling on the product quality attributes. This is because grain that is shipped by bulk has a higher chance being tampered along the transportation chain from origin to destination.

The fourth disadvantage of bulk transportation versus containerized shipped as outlined by Prentice (1998) is that container systems allow for a delay of commitment to the final product until the least possible moment. In other words, after a product has been shipped from its origin, bulk transportation does not allow for further tailoring of processed grains to meet buyer specifications. "Bulk handling reduces the foreign miller's opportunity to tailor processed grains to the exact specifications of the buyer. Commitment is made to the quality of the final product, as soon as the grain is commingled at the country elevator" (Prentice, 1998, p. 8).

The final factor that differentiates bulk handling from containerized shipping relates to the total costs of shipping. Bulk systems realize the lowest cost when shipping from farm to port, but this advantage is off-set by the high inventory holding and storage costs accumulated by the importer. Other costs include the costs of physically handling goods shipped by bulk verses the costs associated with container transfers, the pipeline storage costs, inventory cost, quality costs, and finally, time costs of bulk handling also must be considered.

Further supporting this final element of Prentice's argument, Vachal and Reichert (2000) identify differences between bulk and container shipping related to transit time. The analysis is highly applicable to this research as it studies the transportation of wheat, North Dakota's largest export. The approximate shipping time for wheat by a bulk handling system is 97 days versus 21 days by container. "The reduced time in transit not only offers a men's of marketing for the producer that bulk systems cannot, provide, but also helps to reduce costs, such as inventory holds, and increases reliability" (Vachal & Reichert, 2000, p. 7).

Planning for Intermodal Rail

Rail intermodal transports consumer goods of all kinds and has had steady growth over the past three decades. Figure 2.3 displays the increasing traffic of rail intermodal from 3 million trailers/containers shipped in 1980 and more than 12 million in 2006 and 2007 (Association of American Railraods, 2008). Today, rail intermodal accounts for nearly 22 percent of U.S. rail revenue; exceeding the revenues of any other single commodity shipped by rail

Planning for rail haul takes place on three distinct levels: strategic, tactical, and operational (Bontekoning, Macharis, & Trip, 2004). The strategic level to consider when planning for rail haul takes place over a period of years. This level of planning is foundational to the success of rail haul operations as its focus is centered on the organization of service. Specific tasks at the strategic level include determining which rail links will be used, which origins and destinations to serve, and which terminals to use.

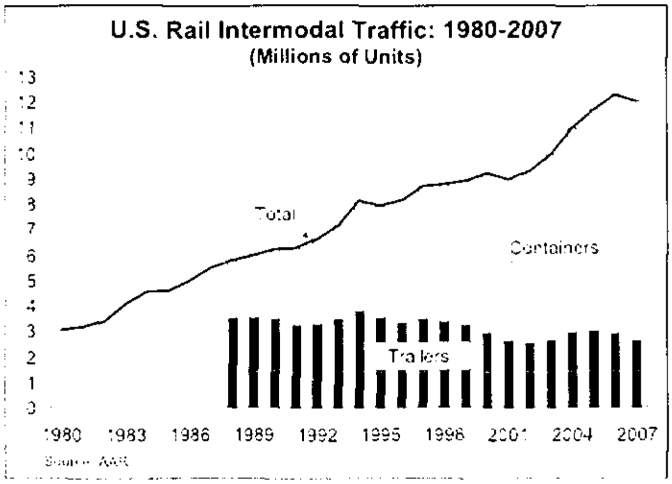

Figure 2.3 United States rail intermodal traffic: 1980-2007

Adapted from The Association of American Railroads "The Value of Rail Intermodal to the U.S. Economy," (2008): 1.

For example, when looking at North Dakota, the strategic options are limited because the BNSF and the Canadian Pacific Railway (CP) are the only two Class I rail networks servicing the state. This is further compounded in that shipments westbound are much easier to achieve than shipments to the east. Shipments traveling east are generally filled with high-valued consumer goods to be unloaded in Chicago, IL; shipments to the going west yield the backhaul of empty being repositioned to Asia.

Strategic planning as defined by Bontekoning et al. (2004) is a vital process to the fabrication of intermodal services. The goals of strategic planning are to minimize transportation costs of rail links, maximize terminal profitability, maximize modal shift away from truck and toward intermodal road-rail integration, minimize total costs of transportation, and minimize the drayage and distance costs (Bontekoning, Macharis, & Trip, 2004).

At the tactical level, subjects regarding train production systems are addressed. Tactical planning takes place over the course of several weeks and considers the matters of train scheduling and routing. Performing the duties of a terminal operator at a port of great activity can be a complex position due largely to the substantial quantity of trains entering and exiting the terminal.

Differing modes of transportation enter and exit the intermodal terminal and operators must consider how to consolidate the aggregate goods. For example, a good that comes into an intermodal facility by truck must be added to the shipment of containers coming in by rail. "Major operations performed in consolidation terminals include vehicle loading and unloading, cargo and vehicle sorting and consolidation, convoy make up and break down, and vehicle transfer between services" (Crainic & Kim, 2005, p. 9). Terminal operators are responsible for reaching economies of scale by assembling loaded trains with goods of uniform port destinations.

Tactical planning includes decisions such as type of vehicle to use for each load, departure times, repositioning of equipment, flows of vehicles and loading, etc. A strategy for terminal operators is to identify and separate the high and low priority cargo. Crainic & Kim (2005) suggest investing in infrastructure (i.e. storage terminals) for each type of cargo in order to create efficiency of consolidation.

Figure 2.4 presents four basic consolidation networks. Terminal operators must continually plan to consolidate based on equipment need, terminal destination, and time constraints. When low-volumes are shipped, the intermodal process to create a seamless door-to-door transferring of goods takes advantage of economies of scale by consolidating goods at the terminal.

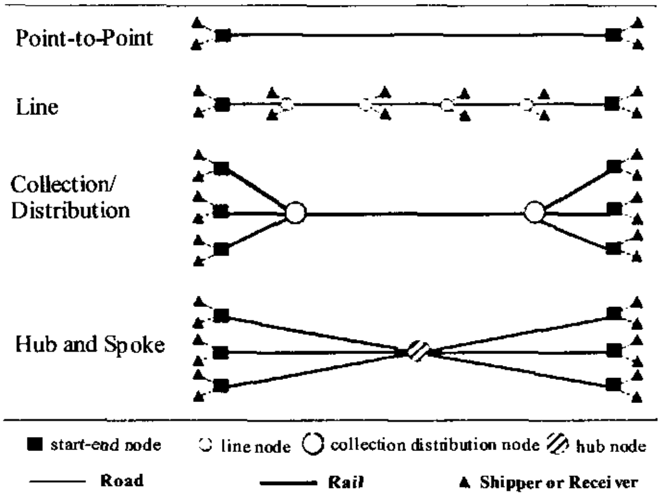

Figure 2.4 Four basic consolidation networks

Adapted from C. Macharis, and Y.M. Bontekoning, "Opportunities for OR in intermodal freight transport research: A review," European Journal of Operational Research (2004): 408.

"Once delivered at the carriers terminal, the cargo of several customers is sorted, grouped, and loaded into the same vehicle or convoy…Containerized cargo is not handled before reaching its destination and, thus, consolidation operations involve only the containers, which are loaded into ships, airplanes, or rail cars" (Crainic & Kim, 2005, p. 9). The element of sealed cargo provides a selling opportunity when guaranteeing quality. Consumers, especially of food products, like the security of knowing their goods have not been tampered or damaged along the chain of transportation.

The final decisions outlined by Bontekoning et al. (2004) at the tactical level include planning the frequency of train service and length. Frequency of service is often be based on shipping volumes. One increasing barrier to terminal operation is railroad demands for greater volumes before they will engage in service contracts (Taylor & Jackson, 2000). This barrier is a key element of this research as it presents a current challenge to the establishment of an intermodal container terminal in North Dakota.

Lastly, terminal operators face day-to-day operational planning. These duties are highly centered on fleet management decisions. Daily planning challenges include the repositioning of equipment, routing a of a container, sizing up trains and optimal distribution of double stack railcars, and assigning trailers and containers to available flatcars (Bontekoning, Macharis, & Trip, 2004). Terminal operators seek to minimize terminal transfers by optimizing load orders.

To summarize, the rail haul portion of the intermodal function realizes economies of scale when used for long-haul transportation. Intermodal rail shipments are more dynamic than bulk rail shipments in a number of ways, but most predominately in the area of fleet management. Finally, intermodal terminal operators must plan for rail transfer on three levels: strategic, tactical, and operational.

Fleet Management

One of the biggest challenges faced by network operators is the need to reposition equipment after it has reached the point of import. Table 2.3 outlines the U.S. trade balance with China and table 2.4 outlines the total U.S. trade balance. The U.S. trade deficit in both tables provides a reflection to the fleet management dynamics faced by network operators: just as the U.S. experiences a trade deficit, foreign ports, such as those in China, experience a deficit of available containers.

The U.S. is not able to export as much as it imports, in other words, the number of filled containers leaving the U.S cannot match the volume of filled containers imported. Thus, containers frequently need to be repositioned as an empty vehicle to the foreign points of export to once again be filled; ocean carriers wishing to complete this cycle as fast as possible to maximize revenues.

Table 2.3 United States trade balance with China 2000-2009 (in millions)

Year	U.S. Exports	U.S. Imports	Trade Balance
2000	$16,185	$100,018	$(83,833)
2001	$19,182	$102,278	$83,096)
2002	$22,127	$125,193	$(103,065)
2003	$28,367	$152,436	$(124,068)
2004	$34,427	$196,682	$(162,254)
2005	$41,192	$243,470	$(202,278)
2006	$53,673	$287,774	$(234,101)
2007	$62,937	$321,443	$(258,506)
2008	$69,733	$337,773	$(268,04)
2009	$69,576	$296,402	$(226,826)

Adapted from U.S. Census Bureau Foreign Trade Statistics

Table 2.4 United States trade balance 2000-2009 (in millions)

Year	Exports	Imports	Balance
2000	$781,918	$1,218,021	$(436,103)
2001	$729,100	$1,140,999	$(411,899)
2002	$693,104	$1,161,366	$(468,262)
2003	$724,771	$1,257,121	$(532,350)
2004	$814,875	$1,469,703	$(654,829)
2005	$901,082	$1,673,456	$(772,374)
2006	$1,025,969	$1,853,939	$(827,970)
2007	$1,148,199	$1,956,962	$(808,763)
2008	$1,287,441	$2,103,641	$(816,200)
2009	$1,056,895	$1,558,085	$(501,190)

Adapted from U.S. Census Bureau Foreign Trade Statistics

Each empty twenty-foot equivalent (TEU) container traveling from the U.S. in return to Asia costs container lines approximately $460 (DRA, 2008). Table 2.5 provides a ten-year span of loaded and empty containers outbound from U.S. Business Economic Area's (BEA's).

Table 2.5 Number of United States outbound containers

Year	Loaded	Empty
1997	2,631,339	660,824
2002	2,867,385	1,320,058
2007	3,713,720	1,665,436
Total	9,212,440	3,646,318

Data adapted from the U.S. public use STB waybill data.

Provided the figure of approximately costing of $460/TEU to reposition an empty container to Asia, and assuming all containers are repositioned to Asia, the total cost to container lines for the years 1997, 2002, and 2007 was approximately $1.6 Billion. Although repositioning containers and other necessary equipment does not directly add to network operator revenues, it is a necessary element of managing container operations and meeting customer needs.

Transshipment

Transshipment is the act performed by terminal operators. As containers arrive at the terminal by truck, they are either directly transferred to a rail car or taken to a storage waiting area. Next, containers taken out of the storage area and loaded onto railcars that are grouped into blocks and trains (Crainic & Kim, 2005).

Transshipping requires a considerable amount of time dedicated to sequencing and scheduling of containers. Terminals must have the capacity to respond drastically when necessary to the changing demands of intermodal and network operators. Transshipment performance can be evaluated on the basis of labor productivity, train reliability, pick-up/delivery cycle times, equipment utilization, service times, throughput time, and train waiting time (Kozan & Corry, 2005).

Terminal operators wish to minimize the overall transshipment time to achieve optimal productivity of train flow and minimize stationary time. The reduction of throughput time is also characterized as terminal operators providing high levels of customer service. Kozan and Corry (2005) provide Figure 2.5 which depicts the typical container terminal set-up in order to minimize operation inefficiencies. "The usual configuration of an intermodal container terminal has the trains side by side, with one or more cranes able to load and unload trains on any track and forklifts able to load and unload trains on the first track" (Kozan & Corry, 2005, p. 1197).

Ocean port transshipment functions are established to provide transfer facilities for containers between sea vessels and in-land transportation modes (Crainic & Kim, 2005). This form of container terminal also performs ship operations associated with berthing, and the loading and unloading of container vessels. This terminal will manage receiving/deliver operations for outside (in-land) modes of transportation. Goods waiting to be loaded are stored in the port's storage yard. Figure 2.6 provides the layout of an ocean port terminal.

Similar to intermediary container terminals, container port terminals also have a general process followed by operators. First, the outside truck arrives to the terminal and is directed toward the transfer point. At the transfer point, a terminal yard crane will lift the container from the truck and stack it according to the operation plan (either directly onto the ship or into the storage yard). Figure 2.5 is limited in that it does not depict the case in which containers arrive by rail. Container port terminals set up with rail lines allow the railcars to enter the facility; once railcars have entered all containers and documents must be examined (Crainic & Kim, 2005).

As containers are imported and prepared for delivery, the yard equipment transships the containers onto an outside truck that leaves the port and is drayed to an intermediary rail terminal or its destination. Transshipment objectives related to container terminal efficiency include, container flow and productivity, minimizing operation costs, and the ability to provide competitive pricing. Development and implementation of scheduling and synchronization for loading is a necessary function of transshipment. Equally important is the efficiency of the terminal layout and storage areas to achieve optimal container flow and reducing overall costs through reducing throughput time (Kozan & Corry, 2005).

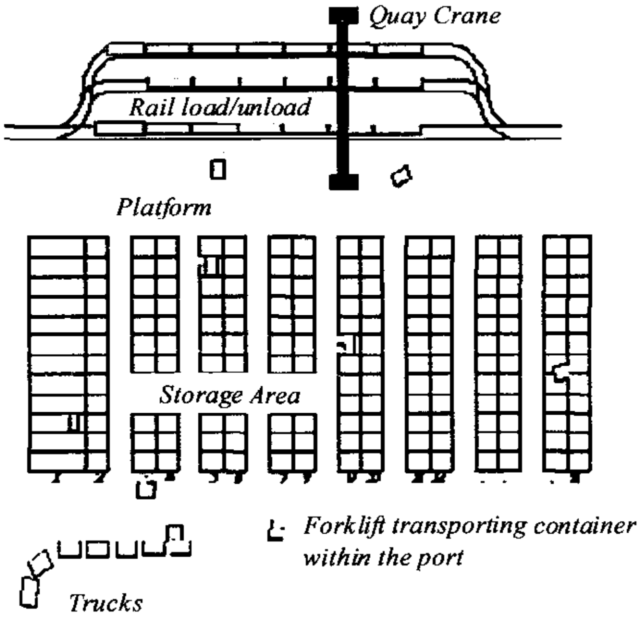

Figure 2.5 Container terminal layouts of intermediary rail-rail terminal

Adapted from Kozan & Corry, "A Real Time Decision Support System for Intermodal Container Terminals," (2005).

Intermodal Chain Management

No single intermodal player can perform the complete list of functions necessary to transfer goods from origin to destination. The synchronization of drayage, rail haul, and transshipment operations requires intermodal chain management. It is argued that the player with most power among all players will assume the role of chain-leader. This research proves ocean carriers to have power superior to other players. Confirming this to be true Bonteking et al. (2004) states, "the actor with the most power in the intermodal chain, can generate overall chain steering…in the international chain, ocean carriers have taken a leadership role" (Bontekoning, Macharis, & Trip, 2004, p. 18).

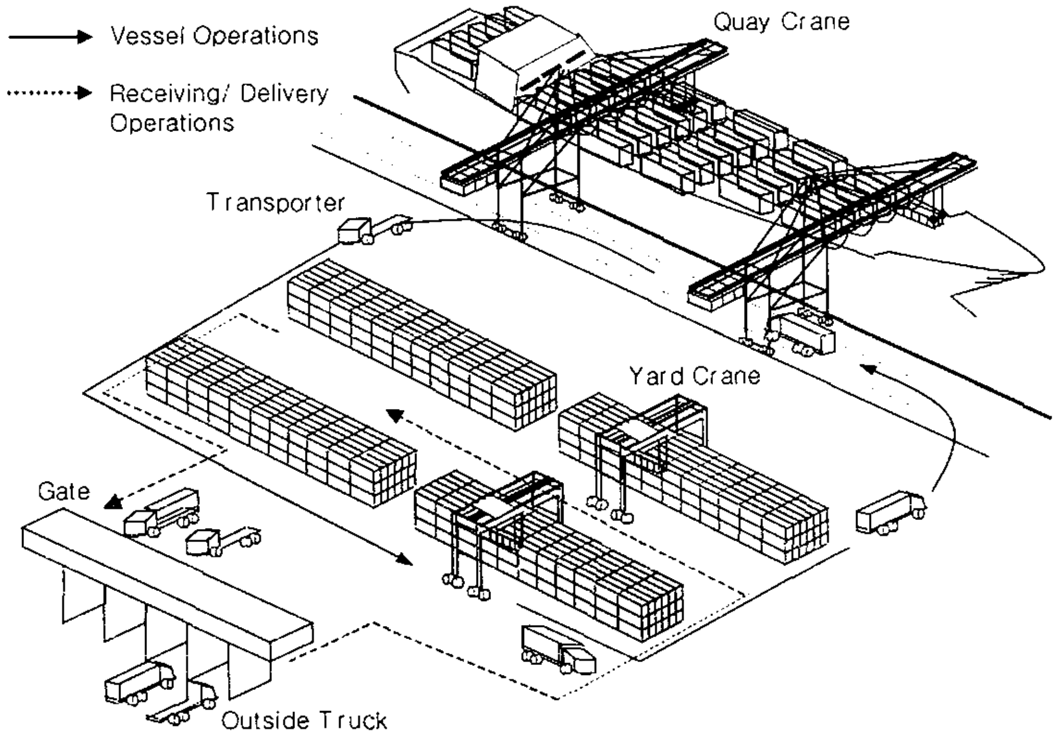

Figure 2.6 Example layout of container port terminal

Adapted from Cranic & Kim, "Intermodal Transportation," (2005).

The function of intermodal chain management proves to play a vital part of this thesis in later chapters. This research seeks a shift from the current industry practices in which all players are in competition to the goal of creating a cooperative scenario. The distribution of costs and benefits across market players is categorized as a function of intermodal chain management.

Pricing Strategies

Each player along the intermodal chain has an implicit level of market power. Network operators are known to have the most significant levels of power. Specifically, ocean carriers are known for leading the market. Although there are a number of ocean carriers in the industry, all have the common goal of making the intermodal round-trip as quickly and efficiently as possible.

Railroad network operators are next in line when considering market power. Often, the rail rate is coupled with an ocean-shipping rate. The intermodal operator interacts directly with ocean carriers (or through a transportation realtor) to receive an ocean and in-land rail-shipping rate. This yields relatively little control for railroads to employ a pricing strategy with their customers.

In addition, all outside players that an intermodal operator negotiates with applies tariff rates to the shippers transported good. "Intermodal agents, railroad, terminal and drayage manager must each have their own tariff (pricing) strategy…to estimate his negotiation power, each actor must be aware of his market position" (Macharis & Bontekoning, 2004, p. 409). In other words, a negative relationship exists between the numbers of intermediaries used to complete a shipping transaction and the shippers profit margins.

It is often beneficial for shippers to utilize the services of transportation realtors. However, it is vital for shippers to analyze transportation options, especially for those producers having already low profit margins. Logistics is a determining factor when making a sale. Orders in which a shipper breaks even may be beneficial in terms of customer service, but high frequency of meeting this break-even point, or in some cases, taking a loss on the sale, do not create a sustainable business practice.

The North Dakota Problem

From 2003 to 2009, North Dakota exports increased 83 percent. During this period, North Dakota led the nation in export growth and experienced an increase from $1.2 billion to the total value of exports reaching $2.2 billion in 2008 (Bjorke, 2010). North Dakota's transportation infrastructure has evolved and centered on meeting the transportation needs of bulk agricultural products. However, the growth in North Dakota exports has lead to an increased demand for a transportation infrastructure to support the intermodal needs of containerized shippers.

This study is centers on the shipping of containers on flat cars (COFC), as such, it is important to identify which North Dakota producers are known containerized shippers: "North Dakota commodities ideal for container movements may include skid steer loaders, mini excavators, value-added wood products and furniture, industrial and agricultural machinery, and agricultural products such as soybeans, confection sunflowers, and organic and identity preserved grains" (Berwick, John, Chi, & Lofgren, 2002, p. i).

The realities of being a land-locked state and not having an intermodal facility within economical range to North Dakota production sites creates a challenge for intermodal operators when competing in global containerized markets. For example, Figure 2.7 displays the relationship between distance to port and profit margins. Scenario one is a shipment from the Midwest requiring inland transportation. Bulk shipments are estimated at $52/ton while container shipments are 44% higher in cost, estimated at $75/ton. Scenario two is for shipments loaded near the port of export. In this scenario ocean costs are the primary focus. As opposed to scenario one, container shipment costs of $10/ton are actually lower than that of bulk shipment costs estimated at $12/ton.

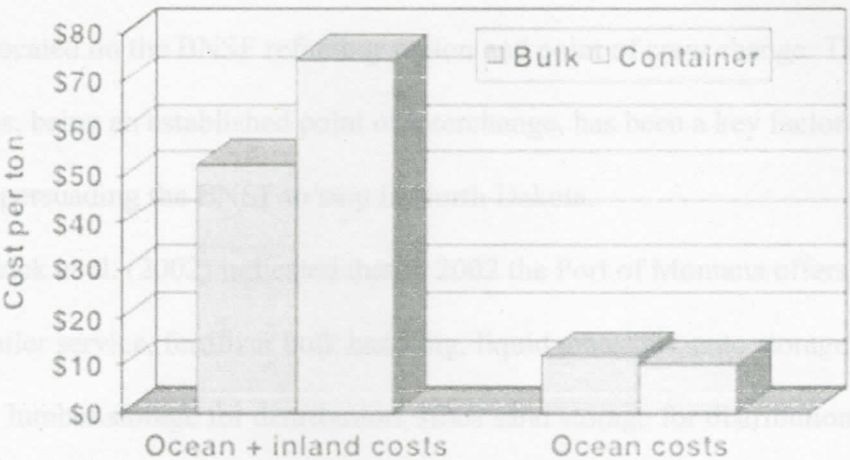

Figure 2.7 Bulk vs. container shipments

Adapted from Heidi Reichert and Kimberly Vachal, "Identity Preserved Grain-Logistical Overview," Economic Research Service, USDA and The Farm Foundation (January 2003): 4.

The North Dakota intermodal problem can be characterized as dynamic, evolved, and persistent. This problem is dynamic as it involves coordination among public and private entities of North Dakota and the cooperation of network operators. In previous years, debates surrounded which potential location to establish an intermodal terminal; Fargo/Dilworth, Valley City, Bismarck, and Minot were the cities in debate. This debate created a significant barrier to developing an intermodal terminal. However, to the benefit of North Dakota exporters, a statewide acceptance has evolved and settled on endorsing one intermodal facility located at the North Dakota Port Services (NDPS) in Minot, North Dakota. This acceptance has come in part by default in order to meet necessary demands of the BNSF.

The Minot location is the only terminal located on the cross-section of North Dakota's two Class I Railroads, the BNSF and the Canadian Pacific Railway. Also, Minot is the only facility located on an intermodal rail line. To Minot's further benefit, the Minot terminal is located on the BNSF refueling station and point of crew change. The latter of these reasons, being an established point of interchange, has been a key factor in persistently persuading the BNSF to stop in North Dakota.

Berwick et al. (2002) indicated that in 2002 the Port of Montana offers container/trailer service, fertilizer bulk handling, liquid materials, auto storage for distribution, lumber storage for distribution, silica sand storage for distribution, and other function requested by customers. Similarities between the Port of Montana and a potential intermodal facility in North Dakota are provided. "Just as the base container traffic for an intermodal facility in Butte is limited, this also is likely to be the case for North Dakota ((Berwick, Bitzan, Chi, & Lofgren, 2002, p. 7)."

The second terminal is an intermodal facility located in Billings, MT. This facility operates to serve less-than-truckload (LTL) traffic. The Billings intermodal terminal is not on an intermodal line and limited container traffic has been a consequence of their geographic disposition. Berwick et al. (2002) makes a strong recommendation to the North Dakota initiative by suggesting any new facility be located on an intermodal line.

Thomas (2008) looked to the Minot initiative for developing a similar, rural intermodal terminal in Cario, IL. The study estimated approximately 3 million empty containers return to Asia annually at a cost of approximately $460 per TEU. Cario, Like North Dakota is seeking to reposition and load empty equipment with agricultural goods.

The Railroad Perspective

North Dakota consists of less than 2 percent of the BNSF's revenue. In order to serve the needs of North Dakota exporters, railroads are asked to position equipment of various sizes (i.e. containers, trailers, chassis, etc.) to a location of relatively minimal volume. The Staggers Rail Act of 1980 and the deregulation of the U.S. railroads have proven to be overall beneficial changes to the rail industry. For example, "Since 1980, intermodal traffic volumes have increased eight-fold. In 2007, railroad intermodal traffic in the U.S. exceeded 14 million units" (Wu & Markham, 2008, p. 4).

However, one shortfall of deregulation is that now privately owned and financed railroads are left to financially support themselves through generating adequate capital to sustain and expand their businesses. Intermodal investment by Class I railroads from 1980 to the year 2000 reached approximately $34 billion (Brown & Hatch, 2002). During this period the compound annual growth rate of rail intermodal was 5.9 percent. However, railroads struggle to make a return on their intermodal investments. "In 2001, for example, the rail industry's overall cost of capital was 10.2 percent, compared with a return on investment of only 6.9 percent" (Brown & Hatch, 2002, p. 13).

Further hindering North Dakota's success is found inside the containers being transported. Agricultural machinery and construction equipment do not necessarily apply, but many of North Dakota's agricultural commodities exported have very low profit margins. Rail intermodal is referred to as a great revenue business but a poor net revenue business (Morlok & Spasovic, 1994). Exports having already low profit margins do not yield returns adequate for railroads to justify the investment of intermodal equipment. This is the current barrier North Dakota has to face in aligning intermodal efforts with the

BNSF's bottom line to justifying a stop in Minot. Other factors considered by the BNSF include the complexity of moving a leased container among the various modes of transportation and working with other, competing, rail networks to coordinate interchanging trains during the line-haul movements (Taylor & Jackson, 2000).

Demand

The underlying issue faced by North Dakota is that of limited volume with respect to outbound container traffic. In the event North Dakota's export volume would jump to even a quarter of that coming out of Chicago, network operators would gladly stop for containers in Minot. To visualize challenges related to volume, the public waybill data, provided by the Surface Transportation Board, was analyzed to derive export volume of both loaded and empty containers across the United States. Figures 2.8-2.10 display volume concentrations of loaded outbound containers for the years 1997, 2002, and 2007.

Note the four BEA regions that make up North Dakota. The year 2002 is the only time period that displays shading (representing significant volume) over one of North Dakota's four regions; the region shaded is located in the southeast corner of North Dakota. However, it is important to note that this data is representative of approximately 10 percent of total outbound traffic. Therefore, even though a Business Economic Area (BEA) may appear to have no container traffic, it is more accurate to say the container traffic in that particular BEA is minimal compared to volumes at the national levels of container traffic. The lack of complete information is most likely the cause for blank regions across North Dakota in the year 2007. North Dakota's export growth between the years of 2002 and 2008 were the most significant in the state's export history and is not represented on the 2007 GIS map.

<u>**Overall Container Market by Export BEA**</u>

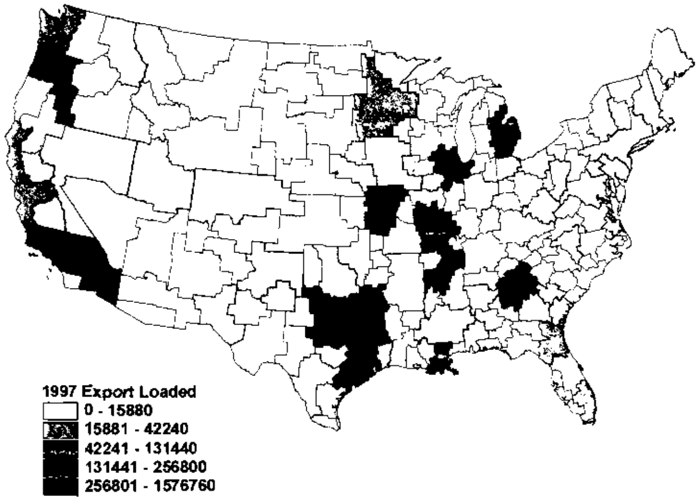

Figure 2.8 GIS map, loaded container export origins 1997

Adapted from Public Waybill Data (2007).

Surveys of Potential Container Demand

A number of public and private feasibility studies on establishing an intermodal terminal in North Dakota have been conducted since the early 1990's. In 2002, the Upper Great Plains Transportation Institute administered a survey to manufactures with potential of being containerized shippers in North Dakota; the survey represented 47 percent of the total workforce surveyed (Berwick, Bitzan, Chi, & Lofgren, 2002).

The survey found outbound modal shares for products leaving the region to include: 53 percent by truck, 45 percent by rail, and 2 percent by container. Many surveyed reported their transportation mode choices to reflect time constraints and reliability of service.

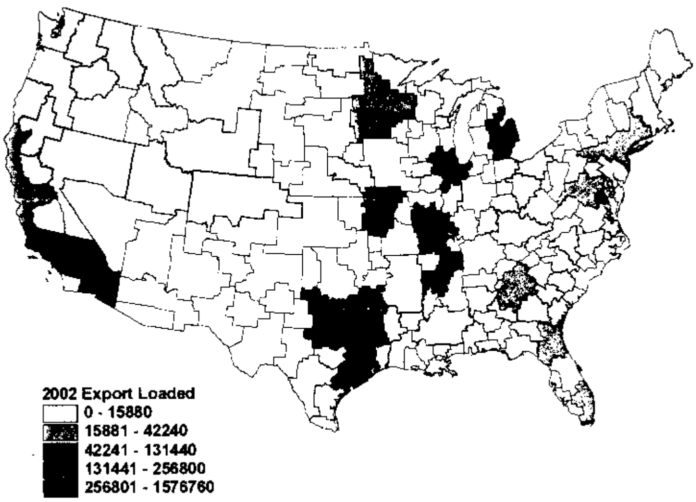

Figure 2.9 GIS map, loaded container export origins 2002

Adapted from Public Waybill Data (2007).

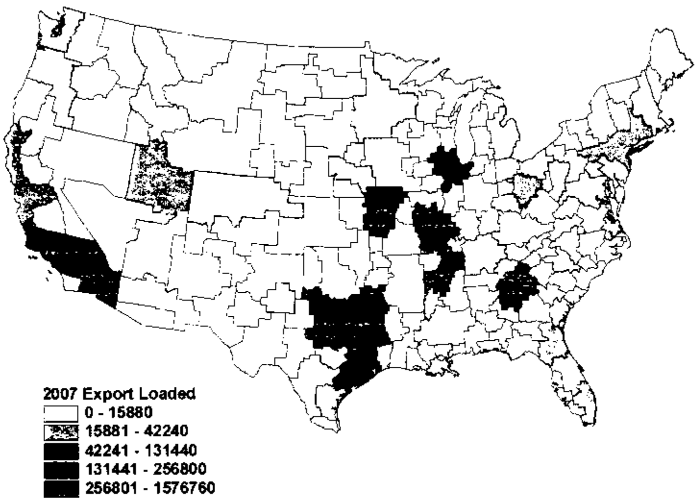

Figure 2.10 GIS map, loaded container export origins 2007

Adapted from Public Waybill Data (2007).

The survey was used to forecast potential demand for intermodal transportation as outlined by Table 2.6; Figure 2.11 outlines the regions surveyed

Table 2.6 Estimated potential container traffic with a new intermodal facility

Region	Estimated Potential Outbound Containers using 20' Container	Estimated Potential Outbound Containers using 40' Container
MN	7,184	6,530
MT	1,121	1,019
ND1	439	399
ND2	1,230	1,118
ND3	801	728
ND4	4,080	3,709
ND5	809	735
ND6	1,905	1,732
ND7	1,576	1,433
ND8	6,025	5,477
SD1	569	517
SD2	3,384	3,076
Total	**29,123**	**26,473**

Adapted from Mark Berwick, John Bitzan, Junwook Chi, and Mark Lofgren, "North Dakota Strategic Freight Analysis, the Role of Intermodal Container Transportation in North Dakota: Executive Summary," Upper Great Plaines Transportation Institute (November 2002): 12

According to Berwick et al. (2002), in order for an intermodal terminal in North Dakota to be successful it would need to handle between 13,000 and 21,000 containers per year; on the basis of a cost profit analysis. Although potential volumes estimated by the Upper Great Plains Transportation Institute survey meet this minimum level of volume, it is important to consider the relative position of 13,000 to 20,000 containers per year with the national outbound container volume levels. As seen in Figure 2.12, comparatively, North Dakota does not have the capacity to compete on the basis of volume.

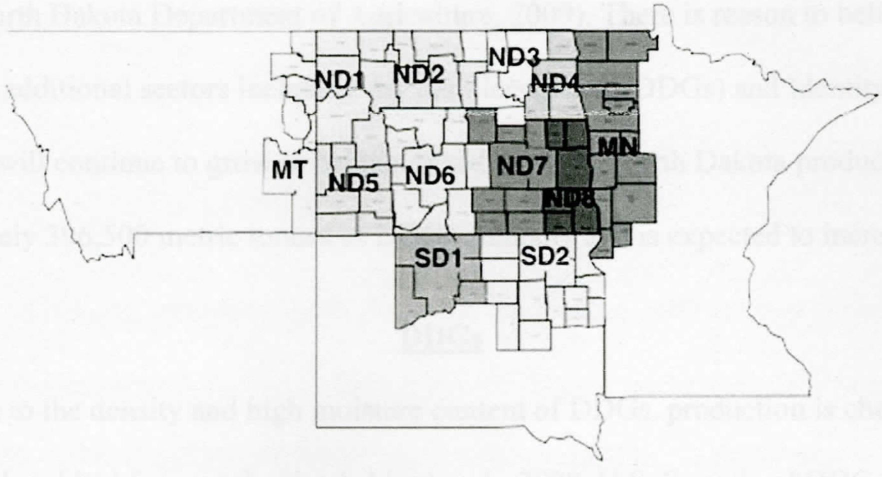

Figure 2.11 Surveyed regions in North Dakota, South Dakota, Montana, and Minnesota

Adapted from Mark Berwick, John Bitzan, Junwook Chi, and Mark Lofgren, "North Dakota Strategic Freight Analysis, The Role of Intermodal Container Transportation in North Dakota: Executive Summary," Upper Great Plaines Transportation Institute (November 2002): 12

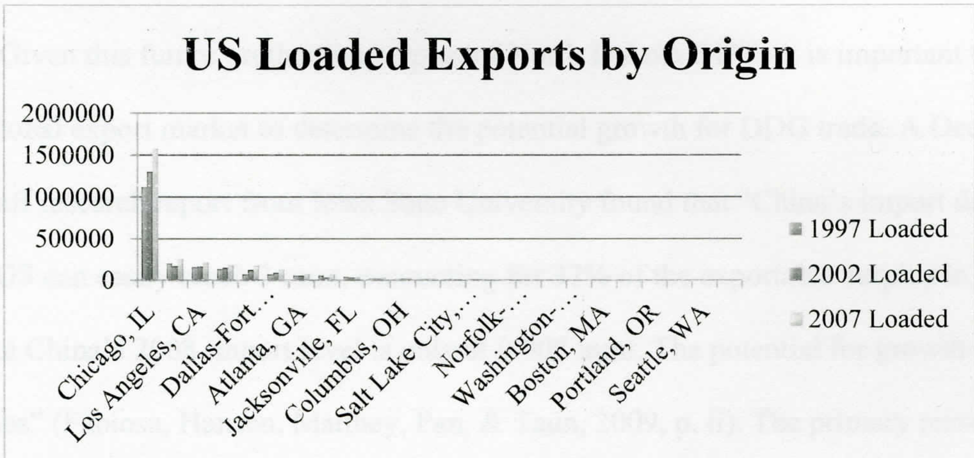

Figure 2.12 United States outbound container traffic by origin

Adapted from Public Waybill Data (2007).

Potential for Increased Demands in North Dakota

Currently, two agriculture sectors requiring containerized transportation, value-added ag processing and farm input manufacturing, generates $1.7 billion in business activity (North Dakota Department of Agriculture, 2009). There is reason to believe these sectors and additional sectors including dry distillers grains (DDGs) and Identity Preserved (IP) grains will continue to grow in containerized demand. North Dakota produces approximately 396,500 metric tonnes of DDGs annually and is expected to increase.

DDGs

Due to the density and high moisture content of DDGs, production is characterized as a by-product ideal for containerized shipping. In 2008, U.S. Exports of DDGs reached 4.5 million metric tonnes and continued to grow in 2009. The majority of DDGs produced in North Dakota are used for domestic livestock feed. However, the North Dakota Department of Agriculture has projected state DDG production to reach 1.72 million metric tonnes per year, providing additional opportunity for export.

Given this future production surplus of North Dakota DDGs it is important to look to the global export market to determine the potential growth for DDG trade. A December 2009 staff research report from Iowa State University found that "China's import demand for DDGS can easily reach 3 mmt, accounting for 37% of the exportable surplus in the U.S., but China's 2008 import level is only at 0.008 mmt. The potential for growth is enormous" (Fabiosa, Hansen, Matthey, Pan, & Taun, 2009, p. ii). The primary reason for DDG demand in China is due to a change in China's consumption patterns.

According to Fabiosa et al. (2009) China has experienced an increase in demand for better-quality food products due to their sustained economic growth of 9.54% over the past decade. The demand of higher quality food corresponds to the increased demand in production of animal-protein-rich foods. "Several studies in the U.S. have indicated that using DDGS in the livestock feed ration reduces feed cost without compromising productivity and meat quality. That is, in a cost-minimization problem for formulating a least-cost diet, DDGS comes out as a dominant ingredient that is always included in the ration at its maximum allowable limits" (Fabiosa, Hansen, Matthey, Pan, & Taun, 2009, p. 3).

Due to the cost minimization benefits, DDG demand will continue to grow with the increasing production of livestock in China. North Dakota is not currently competing for China's DDG demand and should consider exporting DDGs as a significant growth opportunity in the export market. Increasing export volume by trade of DDGs will greatly increase North Dakota's opportunity for a more efficient logistics system.

IP Grains

The growth in IP and Specialty Grain markets is due to the value added by a specific trait such as method of growing or unique compositional characteristic (Golbitz, 2009). According to Wu & Markham (2008), IP grains require documentation pertaining to the "chain of custody" from production site to end-consumer. Also, IP grains are shipped in smaller lot sizes and cannot have cultivar contamination. Due to the very specific shipping requirements of IP grain, containerization is the only transportation option for hard IP producers.

Wu & Markham (2008) also outlines three reasons for container shipping: 1) Shipping IP grain by container satisfies consumers with specific shipping needs, 2) container shipping of IP grain provides producers with greater control over their product along the transportation chain, and finally, 3) The value that is added from utilizing a container for shipping allows for higher profit margins.

This indicates that a North Dakota shipper making a sale to a Korean customer can ensure a seal of quality through utilizing containerized shipping. The producer fills a container and conducts quality tests of the product. Once the producer has determined the product meets customer specifications, the loading unit, in the case of this research a container, is sealed. Sealing the container on-site allows the producer to guarantee uniform quality of their product from origin to destination.

Figure 2.13 outlines the growth of U.S. containerized grain exports to Asia. Due to food safety requirements and the growth of the IP, value-added, and organic markets these figures are expected to continually increase over time.

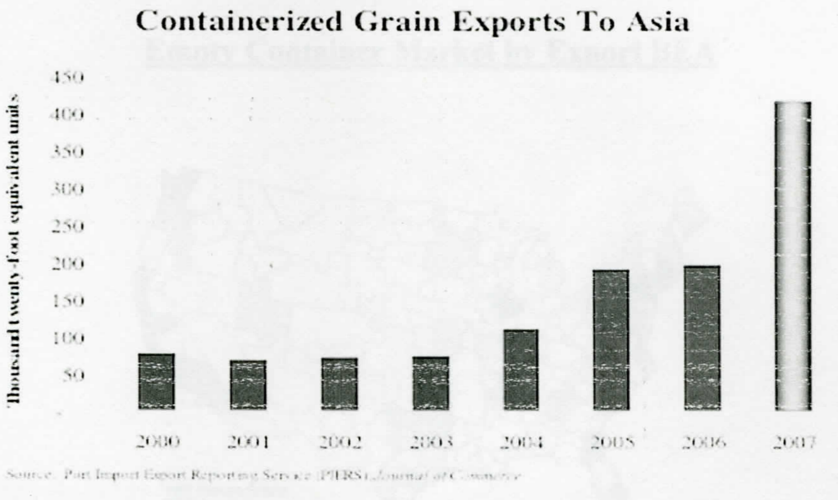

Figure 2.13 Growth in containerized grain exports to Asia

Adapted from Fang Wu and Kurt Markham, "Assessing Feasibility of Intermodal Transport of Agricultural and Related Products on Short Line and Regional Railroads," Minnesota Department of Agriculture (August 2008): 17.

Allocation of Equipment

Not having an intermodal facility in North Dakota creates a barrier to growth in the containerized shipping markets, as container availability is limited. The increasing demand for containers and the reality of many rural Midwestern regions exporting greater container volumes than they import poses a current challenge for North Dakotan producers in locating available containers. For his reason Schuster (2010) states, "empty containers can become scarce at Midwestern rail ramps like Minneapolis and Chicago." The backhaul of positioning a container to production sites can account for a significant portion of transportation costs (up to 40%) making it vital to analyze the distance to available equipment.

The public waybill data was again analyzed to identify regions of container surplus. The data indentified the number of empty containers exported during 1997, 2002, and 2007. Figures 2.14-2.16 display the concentration of empty containers.

Empty Container Market by Export BEA

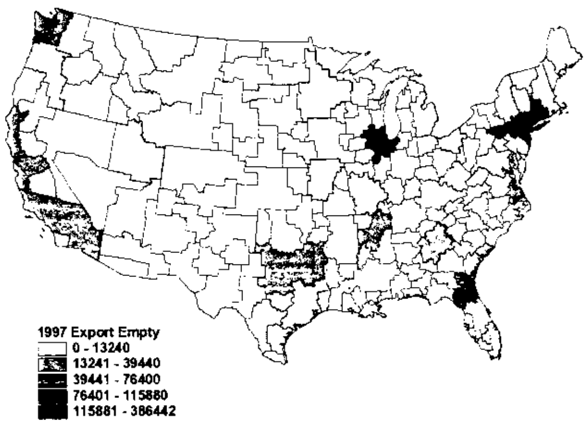

Figure 2.14 GIS map, empty container export origins 1997

Adapted from Public Waybill Data (2007).

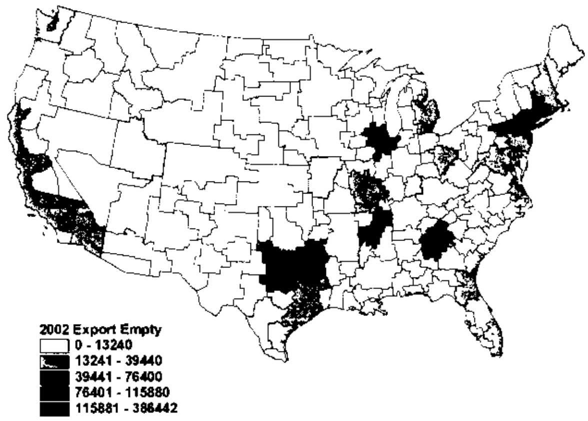

Figure 2.15 GIS map, empty container export origins 2002

Adapted from Public Waybill Data (2007).

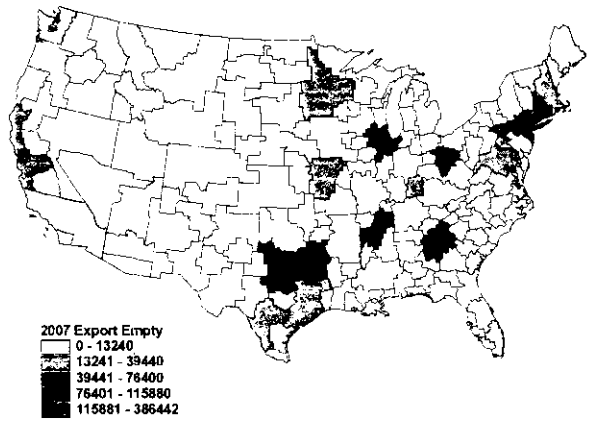

Figure 2.16 GIS map, empty container export origins 2007

Adapted from Public Waybill Data (2007).

The economic downturn from late 2008 through 2009 decreased US imports from 146 million TEUs to 130 million TEUs. Although exports have also decreased during this time, finding empty containers has become increasingly difficult. Many of the empty containers that are positioned to North Dakota are originate from Asia and move by truck from Minneapolis area to ND production sites. In summary, Figure 2.17 displays a chart of empty container allocation across the U.S. in 1997, 2002, and 2007. Note that empty containers located at ports closest to North Dakota, Minneapolis-St. Paul Kansas City, and Omaha are in the bottom half of the container surplus list.

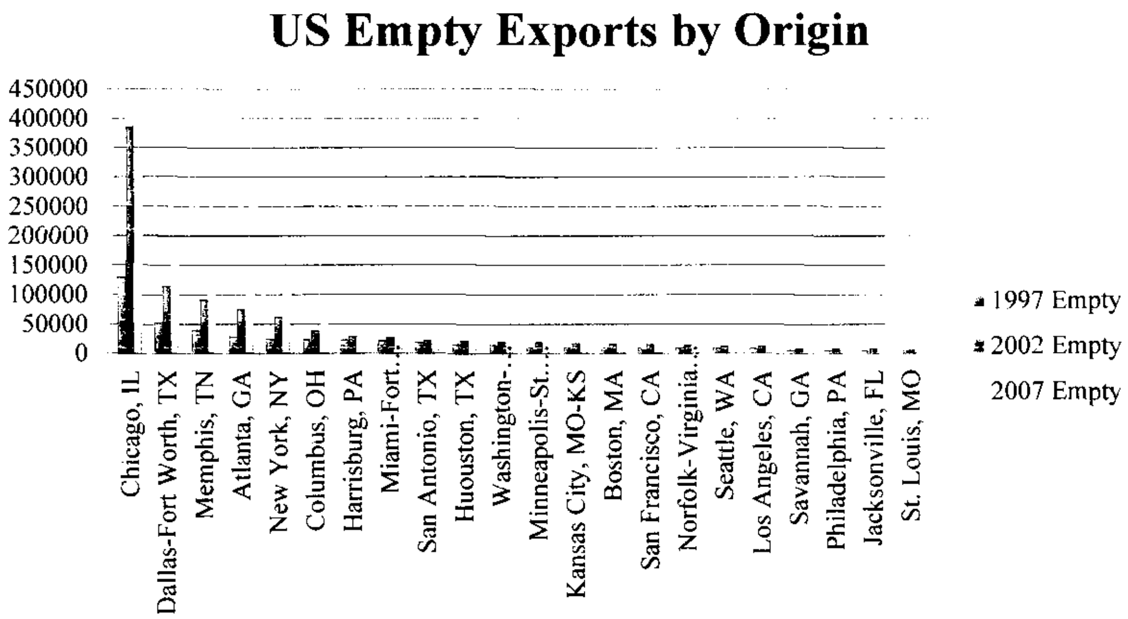

Figure 2.17 Allocation of empty containers

Adapted from Public Waybill Data (2007).

Background Summary

North Dakota cannot compete with national volumes of outbound container traffic. Working with the railroad to reposition equipment to North Dakota and schedule routine intermodal services to Minot, ND are accomplishments yet to be realized. Growth in outbound container traffic is promising when considering the growth in specialty and IP grains, DDGs, and organic product markets. However, one barrier to this growth, without having an intermodal facility in North Dakota, is the availability of empty containers.

Aligning all forces in repositioning equipment and satisfying demand requirements to operate successfully for all players will be the key to establishing an intermodal facility in North Dakota.

Previous Studies

Topics cover in this section include: economics of intermodal transportation, applications of linear programming to transportation, and the North Dakota problem. Several studies have examined the economies of operation associated with shipping containers. More specifically, the first section analyzes port and container terminal efficiency. Part two of explores linear programming methods to determine the economies of operation. Section three relates to the establishment of an intermodal terminal in North Dakota. Studies on this topic were limited, but all provide useful foundational information to how the issue has evolved to where it is today.

One of the greatest barriers to North Dakota's success is the ability to ensure minimum the volumes required by the BNSF. Studies reviewed on estimating demand provided a means for considering modal shifts toward utilizing intermodal transportation over other modes. Studies specifically related to the North Dakota initiative were reviewed to provide insight to the costs and benefits of establishing an intermodal facility in the state. These studies also provided two intermodal facilities in Montana used as a benchmark for North Dakota to strive toward.

Economies of Operation

Hayuth (1988) reviews the efficiency of ocean port terminals. It was found that the upper 20 percent of ports, in terms of number of TEU volume, control the majority of inbound U.S. container traffic. For example, the west coast's largest ports of Long Beach, Los Angeles, Oakland, and Seattle handle 84.4% of the total United States west coast container traffic. Hayuth (1988) presented changes in the United States port system and concentration of traffic flows upon introduction of the container and intermodal transportation.

The degree of concentration was analyzed using the methods of the Lorenz Curve and Gini Coefficient. The Lorenz curve measured the cumulative percentage of port size in comparison to the percent of container ports total (thirteen ports were analyzed). All ports being equal, the Lorenz curve forms a diagonal line; deviation from this line indicates concentration. The Gini coefficient represents concentration as the area between the diagonal line[1] among ports and the Lorenz Curve.

Hayuth (1998) concluded that economies of operation among intermodal players yielded a fewer number of ports servicing the largest ocean vessels. Fewer port stops increase vessel efficiency and port time. Steam lines will select ports to regularly utilize in order to form strategic relationships. Developed port relationships yield a decreased ocean carrier voyage cost as well as decreased port service charges.

Hayuth (1998) also concluded that a steam operator with a large number of containers ready to unload has the upper-hand to negotiate reduced rates on the basis of volume. The study found that over time the value of the Gini coefficient decreased indicating a trend toward a more evenly distributed port traffic. Before intermodal, general cargo ports serviced a smaller hinterland reach. Containerization has extended the geographic reach that each port is able to service.

[1] The diagonal line representing equality

Container Terminal Efficiency

Kozan (2006) developed an analytical based simulation model to investigate train delays and determine the optimal balance between operational costs and costs accrued from train delays. The model assists in understanding the behavior of intermodal terminals and evaluates operational strategies. To analyze this objective a simulation method is use due to the complexity and large number of mathematical models necessary to capture intermodal functions. The simulation method allows for standard and non-standard probability distributions to be included in the model. Mathematical and theory models are determined inappropriate as they may not allow for non-standard probability distributions.

The simulation tool, ARENA was used by Kozan (2006) to develop the analytical model. Sensitivity tests were ran using the key variables of arrival and handling time to determine potential improvements to bottlenecking. It was vital that bottlenecking of trains is analyzed, especially in the case of larger terminals, as it leads to increased train delays decreased terminal efficiencies. Next, cost analysis methods were utilized to find strike an optimal balance between train delays and daily leasing/operating costs to minimize terminal total costs.

Leasing/operating costs were defined as functions of intermodal equipment. This equipment included forklifts, stackers, and cranes. Train delays were analyzed as functions of delay time and penalty cost for delay. This indicated that total costs are defined as being equal to the sum of leasing/operating costs and the costs of train delays.

Kozan (2006) concludes costs to be minimized by spending less on reach stackers and gantry cranes and more on forklifts. The simulation determined the most cost effective and operationally efficient configuration of terminal equipment. Also determined by the simulation was an optimal and realistic container transfer process container transfer terminals across the globe.

Evers (1994) sought terminal economies of scale by introducing a method of risk-pooling among intermodal terminals. This idea is applicable to the cooperative theory developed in chapter four. The research was largely focused on inventory and capacity constraints. Consolidation of adjacent terminals was introduced as a risk-pooling strategy. However, methods of risk pooling were also investigated from the standpoint of terminal sharing among railroads.

The data collected from intermodal terminals of Kansas City and Memphis found inventory uncertainty to be greater concern among decentralized terminals. Conclusions related to terminal sharing among railroads suggested that "multi-user terminals could represent a long-term solution to expected intermodal terminal capacity problems stemming from continued traffic growth" (Evers, 1994, p. 61). The research concluded by stated a terminal operator is able reduce risk by rail granting access to all rail networks.

Related Studies

Bottani and Rizzi (2007) focused research efforts on estimating intermodal terminal potential traffic volumes; the analytical model developed evaluates local road traffic share. The model developed was to assist determining design and location details of potential intermodal terminals and assess the performance or need for expansion of existing facilities.

The approach taken by Bottani and Rizzi (2007) assigned freight flows and potential probabilities to a modal shift toward intermodal traffic. This was achieved by analyzing distance, travel time, and the type of good being transported. Freight flows were based on the "affinity index" (AI), assessing efficiency of an intermodal terminal to handle freight flows compared to other modes of transportation.

The affinity index ranges from values of zero to one. An AI value of zero signifies the lack of a potential modal shift. Conversely, an AI value close to one signifies a high probability of modal shift toward intermodal transportation. AI values being a function of distance, time, and type of good, considered the origin and destination of each freight flow.

Bottani and Rizzi (2007) analyzed the methodology proposed above in a case study determining the success of potential container traffic to an intermodal terminal in Northern Italy; Parma Intermodal hub. The results found a potential volume of approximately 2.5 million tons could be shifted from road to intermodal transportation per year. Their research concluded that potential volumes generated by the Parma International Hub could sustain a facility. Model results were confirmed appropriate as they demonstrated consistent results, practical applicability, and a robust methodology.

Linear Programming and Intermodal

The objective of Kozan and Corry (2005) was to develop a linear programming model that was assisted terminal operators in decision support and efficiency of terminals. Specific objectives included:

- Increasing efficiency, container flow and productivity, lowering operation costs, and offering competitive pricing;
- Developing and implementing schedule algorithms for loading trains at each terminal;
- Improving container storage area efficiency;

- Improving terminal layout to increase efficiency and minimize total container throughput time;
- Scheduling and sequencing container transfers and locations in a given period of time.

This study develops an analytical tool used to optimize the intermodal functions of handling container terminal equipment, train loading and waiting time, and allocation of rail equipment. The study proposes a binary programming model to determine the arrangement of load units for a given number of transfer units.[2] This model described is referred to as E-Intermodal.

The objective function of the linear model considers handling time and train length. The objective function is subject to a set of constraints ensuring eight restrictions: 1) containers are only assigned to slots of uniform dimensions lots are assigned to only one container and vice versa; 2) every slot assigned is filled; 3) loaded containers are restricted from consideration of being reassigned to different load units; 4) load units are not loaded above their given mass limits; 5) mass trailing each transfer unit does not exceed mass limits; 6) ensures containers are loaded into continuous block with common destinations; 7) containers are loaded onto the appropriate prescribed set of specialized transfer units and 8) enforces separation distances between containers and transfer units (Kozan & Corry, 2005).

Model assumptions include that trucks will collect and/or deliver at least one container and are serviced by only one handling machine; all containers collected and/or delivered by each truck are known. Further assumed is that the train plan is able to dictate the positioning of equipment and containers delivered. For example, grounded containers

[2] More simply, load units are rail cars and transfer units are containers or trailers

are placed next to lift for efficiency and handling machines give highest priority to waiting trucks while wagons are not moved during loading operations. Kozan and Corry (2005) measure performance of a terminal by labor productivity, train reliability, pick-up/delivery cycle times, equipment utilization, service times, throughput time, and train waiting time.

In concluding the article focused on meeting specified objectives through implementation of E-Intermodal. Conclusions also outlined areas of further mathematical development for omitted subsystems of the E-intermodal model. Finally, the article outlined the value of having such a set of sophisticated mathematical equations to assist intermodal operators in terminal planning.

North Dakota and Intermodal

Studies pertaining to intermodal transportation in North Dakota are limited. The most extensive research was conducted by the Upper Great Plains Transportation Institute of North Dakota. Berwick et al. (2002) investigates potential intermodal terminal locations as well as a feasibility study for the success of a terminal in North Dakota. It concluded that a North Dakota terminal to cover operational costs it would need to move at least 13,000 containers each year.

Container volumes are estimated by administering a survey to potential users of a North Dakota intermodal terminal (Figure 2.10). Also determined were the types of producers that would benefit from having a container terminal. It was concluded that the eastern border of North Dakota has the greatest volumes for potential container traffic, but lack vial rail capabilities. Berwick et al. (2002) investigates North Dakota intermodal opportunities by looking to Montana's intermodal success. Two Montana terminals are found to reflect potential business models to be followed in North Dakota. The first terminal, The Port of Montana, is located in Butte. The facility was founded for transportation of containers and trailers, but quickly found it needed to encompass other transportation services to survive.

Summary

Chapter two begins by defining intermodal transportation. Intermodal functions are defined in general terms and are then applied to the past, present, and future dynamics of intermodal transportation in North Dakota. A key element to take away from the outline of intermodal functions is the distinction made between bulk verses containerized shipping. Looking to the North Dakota problem, key elements include the significant difference between North Dakota's demand levels for containers relative to the National levels and the potential areas North Dakota might consider expanding in order to reach greater levels of demand (i.e. DDGs and IP grains). A brief review of previous studies on the economies of terminal operation, linear programming applied to transportation, and the North Dakota intermodal initiative concludes chapter two.

Studies reviewed were beneficial in providing knowledge to motivate the development of an analytical model used for this research. More specifically, a cooperative game theory model will be employed using linear programming methodology similar to the risk-pooling methods reviewed. Also beneficial are studies related to potential container demand for intermodal facilities as the North Dakota problem is centered on volume.

The research conducted by this thesis looks to contribute to the limited existing literature to the North Dakota initiative. A review of precedent obstacles is compared to those currently faced by North Dakota's transportation environment and intermodal operators.

CHAPTER III. THEORY

Introduction

Decision making for intermodal operators primarily focuses on maximizing profit or cost minimizing operational costs. The freight costs of a container via each route (i.e. drayage, rail, ocean carrier), storage costs, time costs, and opportunity costs are all considered when making a sale. The objective of any intermodal operator is to determine the route and quantity shipped by each route that optimizes available resources.

This chapter reviews optimization theories to determine the most efficient combination of transportation shipments from product origin to its final destination. Given the dynamic nature of intermodal transportation, the large number of variables, and constraints applied add complexity to the model. By examining the network flow model and keeping the goals of optimization in mind, a transportation strategy for North Dakota exporters is developed. The second section of chapter three reviews the mechanics of game theory. Cooperative games theory is introduced and analyzed in application to establishing an intermodal terminal in North Dakota. Section three connects optimization methods and cooperative game theory. Collectively, this chapter outlines an extensive review of the theory and modeling challenges encompassing intermodal transportation.

Optimization Models

Optimization models consider the maximization/minimization of some volume. This task is the objective in all problems analyzed using linear programming methods. Applying this form of mathematical modeling to a real world situation requires one to consider the values that are to be determined by the model (decision variables), any restrictions applied to the model (constraints), the performance measure of the analyzed problem (objective function), and the numerical data collected and entered into the model (parameters). In order to be considered a linear program, the objective function and all constraints must be linear functions of the decision variables (Anderson, Sweeney, & Williams, 2004).

Given these factors, a linear programming model generates a range of feasible solutions that satisfy model constraints. However, the problem must be further examined to generate an optimal solution among all feasible solutions. This optimal solution results in the largest/smallest possible objective function when solving a maximizing/minimizing problem. In application to transportation, this entails generating a range of transportation options captured by the network flow model to minimize transportation costs.

First, the goal is to transform any given verbal statement into a mathematical form. It is vital that the problem at hand is understood and a clear objective has been outlined. The first step in transforming a verbal statement into a mathematical problem is to express the objective function in terms of the given decision variables. Next, each constraint must be expressed mathematically. For example, given two decision variables a constraint is applied when production capital is limited to $30,000. To transform this statement mathematically, the constraint ($30,000) must be expressed in terms of the decision variables: $X_1 + X_2 \leq 30{,}000$.

Determining an Optimal Solution

It is not necessary to consider all feasible possibilities when determining the optimal solution of an objective function. A graphical representation of the objective function subject to the set of constraints will outline the feasible region. Only the extreme points of the feasible region need to be considered to find an optimal solution. Extreme points are the corners or vertices of a feasible region. The optimal solution to any linear programming model is found at an extreme point, where there is tangency between the set of constraints and the objective function.

Decision makers also find value in obtaining information related to production requirements at their given the levels of capacity. The information is achieved through substituting the optimal solutions of the objective function into the constraint equations. The substitution process provides an allocation of available resources determined by the optimal solution. Any unused material in the production process is referred to as a slack. In a typical linear programming model, any unused or idle capacity for a $\leq$ constraint is referred to as the slack associated with the constraint. Similarly, a surplus variable is added to $\geq$ constraints (Anderson, Sweeney, & Williams, 2004).

Although this research does not study unused capacity is represented by slack variables added to the objective function. The coefficient of a slack variable is zero because it makes no contribution to profit. In general terms, the slack/surplus variables provide information on the difference between the left hand side variables and the right-hand sides of the constraint equation. The standard form of a linear model is achieved when all variables are nonnegative and all the outlined constraints are expressed as equalities.

Sensitivity Analysis

Sensitivity analysis is very useful when asking what-if questions about the model. Sensitivity analysis is a tool used to determine how the optimal solution is affected by a change. These changes may occur in one or more objective function coefficients, and/or changes to the right-hand side variables. Running this form of test on the optimal solution while taking changes into account provides an incremental affect of each change to the optimal solution. When operating in a dynamic environment, having uncertain coefficient estimates, the sensitivity analysis provides higher levels of information to the decision maker. Decision makers utilize this information to ensure efficient operation.

Reduced costs are used for examining cost minimizing alternatives to the optimal solution. In other words, a reduced cost provides the amount by which an alternative shipping solution would have to decrease to become an optimal solution. Reduced costs are provided for each shipping alternative to the optimal solution and are used by chapter five to report model results.

In summary, optimization models provide an optimal solution, or best option, for a given problem at a particular period of time. The optimization principle assumes that decision makers experience higher levels of utility with increased profits and/or decreased costs. Reduced costs are added to determine alternatives to the optimal solution. Finally, conducting a sensitivity analysis provides information incremental changes of an optimal solution given a change in either an objective function coefficient or right-hand side variables.

Optimization models are often applied to transportation and transshipment problems. Examples might include the timing of traffic lights, scheduling of flights arriving and departing from major airports, and analyzing the wait time for each stop a bus will make along a particular route. For the purpose of this research, an optimization model is applied to intermodal transportation in North Dakota and analyzed using the synthesis of transportation and transshipment optimization.

Optimization and Transportation

The transportation problem as examined by Anderson et al. (2004) arises frequently in planning for distribution of goods and services from several supply locations to several demand locations. Typically, when analyzing optimization models in transportation, supply is limited and demand is known. For simplicity, the supply and demand has been specified in the model developed in chapter four.

One method of applying linear programming to transportation analyzes the minimum cost of shipping goods while satisfying supply and demand limitations. This section of chapter three discusses the general transportation model and then continues one step further to explain the transshipment problem; a variation of the transportation problem.

The Transportation Problem

Analyzing the transportation problem by methods of linear programming provides *m* sources of initial shipment and *n* final destinations. This basic notation of the transportation problem is represented by (Anderson, Sweeney, & Williams, 2004):

x_{ij}= number of units shipped from origin i to destination j;

where i= 1, 2,..., m and j = 1, 2,..., n.

For example, when considering the transportation problem for the shipment of containers by rail we look to intermodal facility locations located near North Dakota production sites as the shipping source and locations such as the PNW and Los Angeles as shipping destinations. Table 3.1 outlines arbitrary cost per unit figures from Minot, Minneapolis, and Winnipeg to the PNW and Los Angeles.

Table 3.1 Transportation cost per unit

	Destination	
Origin	Pacific Northwest	Los Angles
Minot	3	5
Minneapolis	2	2
Winnipeg	2	3

Following the basic notation of the transportation problem, the cost of shipments leaving Minot = $3x_{11} + 5x_{12}$; the cost for shipments leaving Minneapolis = $2x_{21} + 2x_{22}$; and the cost for shipments leaving Winnipeg = $2x_{31} + 3x_{32}$. This notation is used in later chapters when building and analyzing the model related to North Dakota intermodal shipping.

The network flow of shipping goods between the initial source and final destination is displayed on a graph as seen in Figure 3.1. The circles (nodes) in Figure 3.1 represent initial sources and final destinations for shipping good x. The lines represent the cost associated with shipping good x from origin to destination nodes are known as an arcs (distribution route).

The demand and supply figures outlined in Figure 3.1 introduce network constraints. These constraints are necessary to include in the model; each transportation origin has a limited supply and destinations a limited demand. As outlined in previous chapters, the supply of containers originating in North Dakota ultimately determines the success of an intermodal facility in Minot.

Again looking to Figure 3.1 the supply constraints of this assumed model are: $x_{11}+ x_{12} \leq 12000$ (Minot Supply); $x_{21}+ x_{22} \leq 25000$ (Minneapolis Supply); $x_{31}+ x_{32} \leq 20000$ (Winnipeg Supply). Similarly, the demand constraints are noted as: $x_{11}+ x_{12}+ x_{13} = 100000$ (PNW Demand) and $x_{21}+ x_{22}+ x_{23} = 150000$ (Los Angeles Demand).

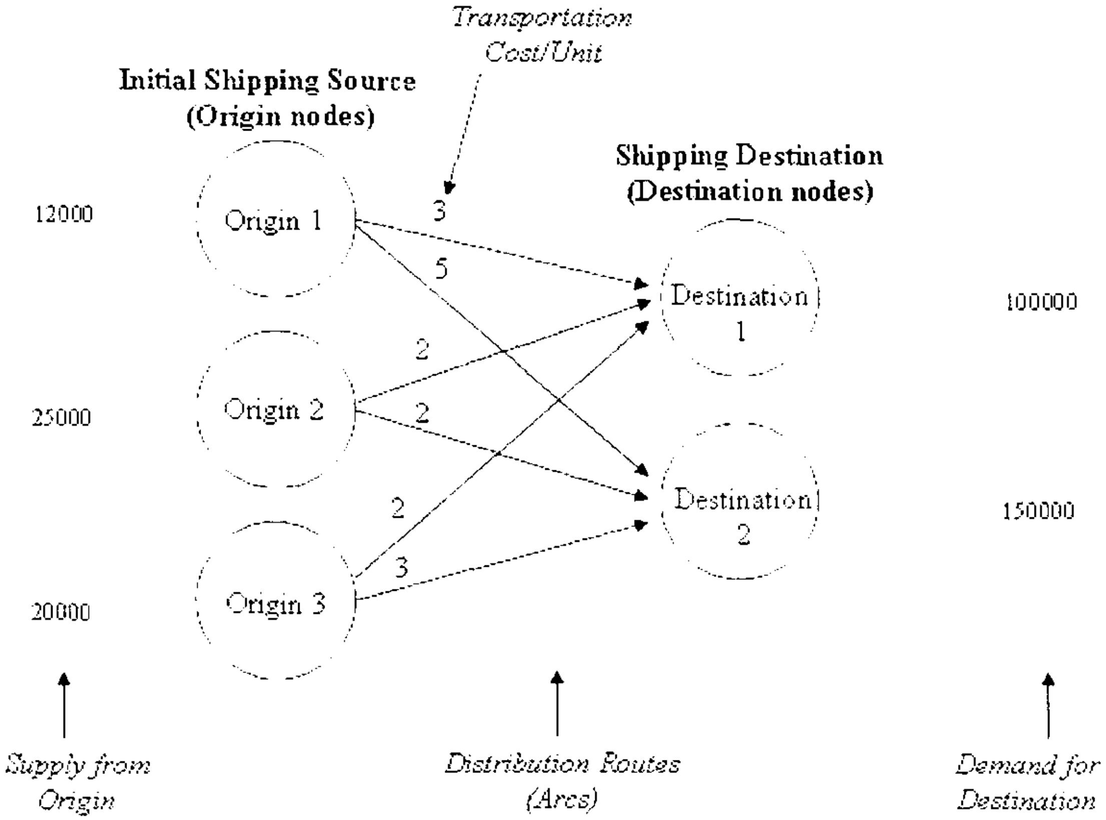

Figure 3.1 The network representation of the transportation problem

The network flow model displays all necessary information for building an optimization model. The sum of the goods shipped from each location must be less than or equal to the supply of each origin and the sum of all goods shipped to a destination node must be less than or equal to demand. However, in the event that supply is less than total demand, a dummy origin and connecting arcs can be added to the model. The dummy origin having a supply value equal to the difference between the total demand and total supply creates a feasible solution for the optimization model. A zero cost per unit is assigned to each arc leaving the dummy origin, this allows for the optimal value to represent shipping costs for units actually shipped. When the optimal solution is implemented the destinations having shipments originated from the dummy are destinations experiencing an unsatisfied demand (Anderson, Sweeney, & Williams, 2004).

If the objective of the optimization model is to maximize net revenue rather than minimize cost, the costs per unit outlined on the arcs of the network flow model are replaced by net revenue per unit coefficients[3]. The constraints remain unchanged. In either case, seeking to maximize or minimize the variable definitions used in the basic transportation model is:

i = index for origins, $i = 1, 2, \ldots, m$

j = index for destinations, $j = 1, 2, \ldots, n$

x_{ij} = number of units shipped from origin i to destination j

c_{ij} = cost per unit of shipping form origin i to destination j

s_i = supply or capacity in units at origin i

d_j = destination in units at destination j

Because the focus of the network flow model developed in chapter four is on minimizing transportation costs from the m-origin to n-destination, the minimization problem is represented by Equation 3.1.

$$Min \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \tag{3.1}$$

$$s.t.$$

$$\sum_{j=1}^{n} x_{ij} \leq s_i \qquad i = 1, 2, \ldots, m \quad \text{Supply}$$

$$\sum_{i=1}^{m} x_{ij} = d_j \qquad j = 1, 2, \ldots, n \quad \text{Demand}$$

$$x_{ij} \geq 0 \qquad \text{for all } i \text{ and } j$$

[3] Net Revenue= (Price*Quantity)- Cost

For the purpose of this research, focused on exporting containers, it is necessary to take the transportation problem a step further to defining a transshipment optimization model. To fully understand the problem faced by North Dakota intermodal operators, it is necessary to outline transportation costs from the site of production to the destination port (i.e. Cass County to Beijing). The basic transportation model does not account for intermediary nodes such as intermodal facilities. At this node, the goods shipped are transferred from one mode of transportation to another. The transferring of modes has implications on the cost and profit structure of the optimization model. As earlier noted, the drayage of a container can account for up to 40% of the total transportation cost. Being a significant portion of total cost, it is important to build a model that will allow for this and other such dynamics of intermodal transportation.

The transshipment model introduces intermediary nodes to account for transshipment locations, such as the intermodal facility in Minot, ND. "The transshipment problem permits shipments of goods from origins to intermediate nodes and on to destinations, from one origin to another origin, from one intermediate location to another, from one destination location to another, and directly from origins to destinations" (Anderson, Sweeney, & Williams, 2004, p. 431). For the case of Minot, transshipment may occur between more than road and rail; the facility is prepared for operations to facilitate transshipment from rail to rail. This yields additional value to the Minot facility.

Similar to the transportation problem, supply and demand is specified in the transshipment model. The objective however, is to minimize costs or maximize profits of shipping goods across various links of transportation. The network representation of the transshipment model is seen in Figure 3.2.

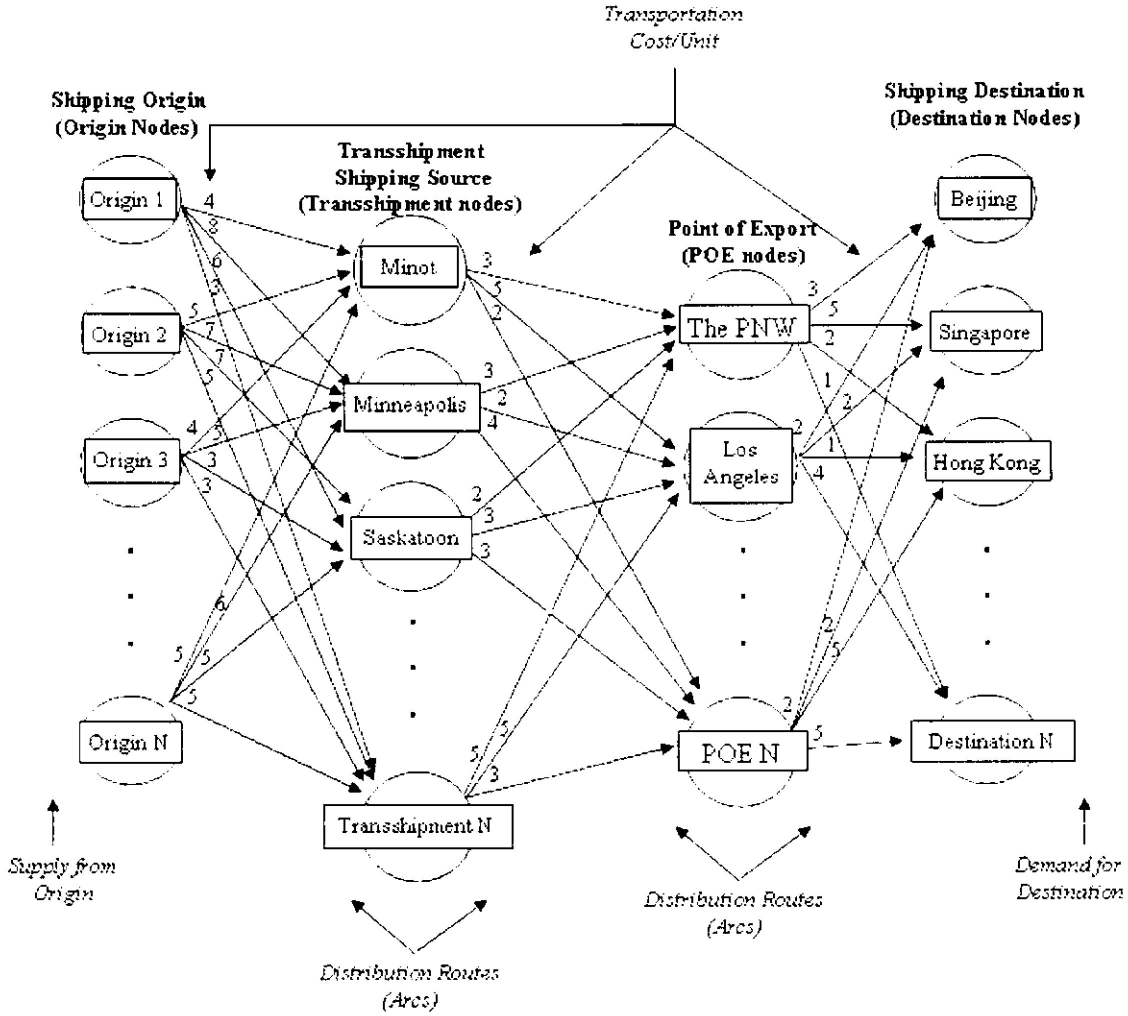

Figure 3.2 A model specific network representation of the transshipment problem

For simplification the origin nodes in Figure 3.2 are generically outlined. The actual model being developed contains 8 origin nodes representing the surveyed regions of North Dakota outlined by Berwick et al. (2002). This provides greater precision when creating a minimized transportation cost model for all intermodal operators within North Dakota.

Recalling that the supply and demand constraints of the transshipment problem remain unchanged from transportation problem, it is important to note that the constraints included for the transshipment nodes include the number of units arriving to and departing from the intermediary node; this applies at both the transshipment and point of export

(POE) nodes. Setting the shipments, or more simply, the number of containers coming into the intermediary node equal to those exiting the intermediary node allows for further calculation of placing all variables on the left-hand side of the equation; yielding the constraint for the intermediary node being examined.

For example, following the assumed transshipment model of Figure 3.2, the number of units shipped out of node 5 (Minot) = $x_{58}+ x_{59}$ and the units coming into node 5 = $x_{15}+ x_{25} + x_{35}+ x_{45}$. Setting the inbound and outbound container traffic equal we achieve $x_{58}+ x_{59} = x_{15}+ x_{25} + x_{35}+ x_{45}$. The final step to determining the constraint for node 5 is to move all variables to the left-hand side of the equation. The constraint for node 5 in the assumed transshipment model = $-x_{15}- x_{25} - x_{35}- x_{45} +x_{58}+ x_{59} = 0$.

This process is applied to each transshipment and point of export node. The general notation used for minimizing transportation cost in the transshipment model is seen in Equation 3.2 (minimization problem).

$$Min \sum_{allarcs} cijxij \tag{3.2}$$

$$s.t.$$

$$\sum_{arcsout} xij - \sum_{arcsin} xij \le si \qquad \text{Origin nodes } i$$

$$\sum_{arcsout} xij - \sum_{arcsin} xij = 0 \qquad \text{Transshipment nodes}$$

$$\sum_{arcsout} xij - \sum_{arcsin} xij = dj \qquad \text{Destination nodes } i$$

Creating an optimal transportation strategy for intermodal operators requires the creation of a minimized cost structure. To achieve this purpose, it is necessary to account for costs associated with transportation, handling, and lost time. Determining the number of goods to ship across various distances and at each mode of transportation at minimized costs is the overall goal of the optimization model developed in the next chapter.

The theories of linear programming and the transportation models outlined above reflect the base knowledge applied to this research. Similar optimization models are developed and analyzed on the fundamental theories of mathematical modeling and optimization. GAMS is the tool being used to optimize the minimization transshipment problem. Output from the linear programming model will be used as inputs in developing the game theory models.

Overview of Game Theory

The goal of developing this game-theoretic approach is to achieve cooperation as an outcome to non-cooperative strategic behaviors among industry players. This approach consists of three stages. The first stage is to determine the types of coalitions to be formed. In our example, one type of coalition is one formed among North Dakota players and another type might be between network operators.

Second, the players must decide non-cooperatively whether or not to sing the agreement (join the coalition). Finally, the players who have chosen to join the coalition act cooperatively against non-signatories continuing operation as a non-cooperative Nash game approach. In this final stage signatories decided cooperatively on what prices to set and how to use combined capacity to maximize the coalition revenues (surplus), while the coalition and singletons compete with one another in a non-cooperative way (Saeed & Larsen, 2009).

Applying game theory to this model will determine whether a group of players is able to operate more efficiently by cooperating. To be determined by the model is the information pertaining to which players are able to operate more efficiently by joining a coalition rather than operating independently. The various combinations of potential coalitions are analyzed until the optimal solution is reached.

In application to the North Dakota container transportation problem, two types of coalitions are formed. First, a coalition among North Dakota players is analyzed. This includes intermodal operators, drayage operators, and terminal operators. Setting all other factors aside, an incentive for North Dakota players to utilize an intermodal facility in North Dakota must be in place. If no incentive exists, intermodal operators will continue operating independently and an intermodal facility will fail.

This first coalition among players seeks to distribute the coalitional revenues among players in such a way that encourages terminal use. For example, again using assume figures, Table 3.2 outlines a hypothetical cost/benefit analysis for North Dakota players operating independently versus cooperatively.

Table 3.2 Cost/benefit analyses for operating as Nash Competitive Game versus operating cooperatively

	Intermodal Operators		Drayage Operators		Terminal Operators	
	Nash Game	Operating Cooperatively	Nash Game	Operating Cooperatively	Nash Game	Operating Cooperat-ively
Costs	50	45	100	100	30	35
Surplus	10	50	150	125	25	75
Cost/Benefit	10	30	150	155	25	65

Notice the total surplus for players operating individually totals 185 (10+150+25=185), whereas the total surplus for the coalition totals 250 (50+125+75=250). For certain players operating under the Nash competitive strategy, the incentive to utilize an intermodal facility may not exist given alternative transportation strategies. For the situation that players are operating cooperatively the total surplus is greater than the competitive surplus.

Thus, even though drayage operators can experience greater profits by operating individually, the coalition can allocate revenues away from one player and toward another to provide the incentive to join the coalition. If this were not the case, drayage operators would continue operating independently as it would be in their best interest to do so. In cooperation revenues are pooled and redistributed in such a way that provides each signatory the incentive to continue operating cooperatively.

The strength and stability of a coalition is examined on the basis of core and characteristic functions. A coalition having transferrable utilities among players is a function, also known as a characteristic function (Saeed & Larsen, 2009). The characteristic function (or worth of a function) states that a function having no members has zero worth. The second property of a characteristic function is known as "superadditivity." This property states that the surplus of two players operating within a coalition must be greater than or at least equal to the surplus each player can achieve by operating independently. The property of "superadditivity" is represented mathematically in Equation 3.3.

$$U(p_1 \cup p_2) \geq U(p_1) + U(p_2). \tag{3.3}$$

When all players are operating cooperatively, the coalition must decide how to divide the total surplus. Core is the set of feasible payoffs that no payer or coalition can improve upon by acting independently (Aumann & Hart, 1992). A core is stable in the event that trade is voluntary and each player is better off than otherwise operating individually, allocation is efficient (pareto optimal), and no coalition of players can find a better trade of its own (Moulin, 1995).

Core has been observed mathematically by Saeed & Larsen (2009). U is an *n*-person game in characteristic function form having players $P = (p_1, p_2, \ldots p_n)$ and $(x_1, x_2, \ldots x_n)$ real numbers. Equation 3.4 captures the rationality of each individual player within the coalition.

$$x_i = U(P_i) i = 1,2,\ldots n. \qquad \textbf{(3.4)}$$

Equation 3.4 indicates that each player within the coalition is willing to participate if it pays at least as much as potential profits provide when operating individually. Equation 3.5 outlines the collective rationality of the coalition.

$$\sum_{i=1}^{n} x_i = U(P) \qquad \textbf{(3.5)}$$

Equation 3.4 shows that the sum of payoffs of *n*-players is equal to the value guaranteed by the characteristic function (Saeed & Larsen, 2009). Payoffs satisfying Equation 3.4 and 3.5 are said to be efficient and individually rational. These payoffs can be viewed as the minimal conditions under which a social agreement can be reached among players.

The model developed in the next chapters analyses the Brandenburger and Nalebuff (1996) theory of Co-opetition. Brandenburger and Nalebuff introduce added value as being the size of the pie when you are in the game minus the size of the pie when you are out of the game. It is continued that player perceptions of their own or another player's added value affect distribution of the pie.

Brandenburger and Nalebuff (1996) encourage professionals to consider their value net and the value net of their competitors; assisting to visualize the game being played. The value net is displayed by Figure 3.3.

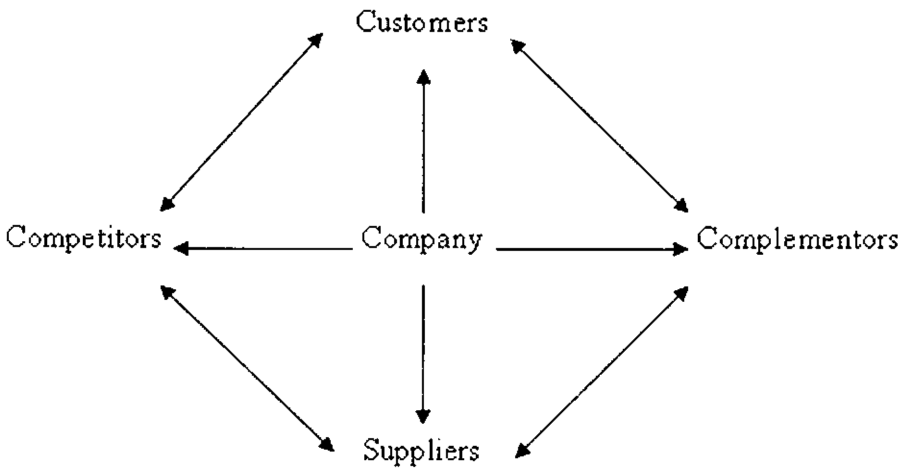

Figure 3.3 A company value net

Adapted from Brandenburger, Adam and Nalebuff, Barry; "Co-opetition," (1996): 23.

The goal of determining a company's individual added value among the value net can provide negation power. The added value of sensitivity is developed looking to the model results. Total value added by all players is known as the coalitional surplus and is determined by the objective function value of each model. The added value of each sensitivity test is used to distribute this surplus.

Analytical Optimization and Cooperation

In order to build a successful model a constraint applied is that demand must be known. The approach taken to meet this constraint has been to limit the research to container transportation for export use only; eliminating domestic container transportation from the model.

Looking to price and demand alone does not provide adequate information for the overall goal in solving the North Dakota problem. The costs derived from the linear programming minimization problem must be applied to the game theory model. Intermodal operators face outside costs related to inland transportation, freight rates charged by ocean carriers, and time costs of transportation. Even though two terminals may have equal handling charges, the outside costs considered may lead to different market shares among players (Saeed & Larsen, 2009).

Utilizing both the methods of analytical optimization and cooperative game theory analyze the North Dakota problem. Research related to intermodal shipping has been at the forefront of transportation research in North Dakota. However, from research articles reviewed, it is determined that this research is the first attempt to solve the North Dakota problem by the methods of optimization and cooperative game strategies.

The two methods are developed as interdependent components to the model. Developing the optimization model is a key element to the model as a whole. Outputs from the analytical optimization model are used as inputs to the cooperative game strategy. In Figure 3.2 there are a number of costs to be derived. These include costs for intermodal operators to ship by container, drayage costs, handling costs at all intermediary nodes, costs of rail haul and rail time costs (money lost by repositioning the trains to North Dakota), freight rates, and ocean shipping costs. Deriving these costs allows for the development of the cooperative game strategy.

The cooperative game strategy will then take all costs into account and determine whether benefits associated with a cooperative strategy can exceed the benefits of a competitive game. If each signatory member of the coalition is not better off, or at least indifferent, by operating cooperatively the coalition fails. Deriving the cost output of the optimization model provides information on the portion of surplus each coalition member needs in order to be satisfied and continue operating cooperatively.

Deriving the optimization model without applying the information to game theory does not achieve the goal of developing a transportation strategy. Optimization and cooperative game theory unite to determine a cooperative strategy for North Dakota exporters.

Summary

Optimization is a key element to any efficient decision making process. Transportation or Logistics (traffic) managers seek to minimize transportation costs across all functions of their business. Chapter three introduced basic principles for building operational efficiency through optimization techniques. The optimization theory is then analyzed in application to the transportation problem.

This chapter introduced a prototypical transportation model to outline the components needing consideration when minimizing total transportation cost. The basic notation for minimizing transportation costs is defined. The network configuration of the transportation provides a visual aid to understanding the complexity of optimizing the problems objective function. In other words, the network configuration outlines all the necessary components of the minimization problem. This includes the decision variables, constraints, and parameters of the model.

Next, a customized transshipment model was developed. This developed transshipment model is an accurate representation of the model used in the following chapters. The transshipment model introduces intermediary nodes, also referred to as transshipment nodes, to the basic transportation model. These transshipment nodes allow for decision makers to utilize multiple modes of transportation along the transportation chain. A truly efficient transportation system for shipments across distances exceeding 500 miles utilize a combination of transportation modes and are now captured by the transshipment model.

Also, a network configuration of the transshipment model is developed in chapter three. This network configuration seen in Figure 3.2 provides the necessary information for minimizing transportation costs across the entire network. The output of the cost minimization problem is then applied to the game-theoretic approach used to analyze a transportation strategy for North Dakota exporters.

The minimized costs derived from the transshipment model provide information to the cooperative game strategy. This information is used in the formation of a coalition among industry players. Once the minimum requirements of individual players have been defined, a coalition can be formed.

Chapter three then discusses the mechanics of cooperative game theory and the goals of forming a coalition. The goal driving any formed coalition is to achieve a greater total surplus by acting cooperatively than can be achieved through competition. It is vital to the success of the coalition that each coalitional member receives greater, or at least equal payoffs to operating individually. Otherwise, there would be no incentive for industry players to operate cooperatively.

The three stages of forming a coalition are introduced. First, the number of coalitions and the potential coalitional members must be defined. For this research two types of coalitions are formed; one among North Dakota players and the other among network operators. Second, the potential coalitional members must decide independently whether or not greater payoffs can be achieved by acting cooperatively. If greater or equal payoffs are potential, the individual player will join the coalition. Finally, the members of the coalition the begin acting competitively against non-signatory players in a Nash Equilibrium game.

Utilizing optimization tools and applying the results to a game-theoretic approach is the underlying theory developed in the following chapters. Examining the methods of optimization and cooperative game theory working together concludes chapter three. Specifically, the final section of chapter three describes the interdependency of the two methods for achieving a transportation strategy. Chapter four considers North Dakota's intermodal challenges by the basic theory introduced in chapter three and develops a model to capture the dynamics of containerized shipping for intermodal operators in North Dakota.

CHAPTER IV. MODEL DEVELOPMENT

Introduction

Increased demand for containerized shipping, whether due to buyer request, infrastructure, and/or quality control has demonstrated a significant market share gain over the past decade. The United States growth rate of containerized trade is approximately 10-11% per year (Fan, Wilson, & Dahl, 2010).[4] This increasing trend has proven important for many North Dakota exporters. With an increasing number of consumers demanding purchased goods to arrive by container, North Dakota exporters are forced to develop a transportation strategy that incorporates the many dynamics of shipping by container.

Not having an intermodal facility located within the economical radius of 150 miles to production sites, North Dakota exporters are not positioned to compete globally. In response, many efforts have been focused toward developing an intermodal terminal in North Dakota. Today, an intermodal terminal exists in Minot, North Dakota, but it is idle. This chapter develops a network model used to capture the reasons why the Minot terminal remains idle. The network flow model, focused on cost minimization, specifies shipping opportunities for North Dakota exporters.

This chapter is organized into the four following sections. To start, an overview of the model is provided; discussing the base case model and sensitivity tests added. Next a mathematical specification of the model is given and an interpretation of the objective function and constraints is provided. The model is based on a number of data sources, thus

[4] Containerized trade did not reach 10-11% in 2008 or 2009; due to global economic factors.

a section is added to outline and credit data used in the model. Finally, the last section provides a summary of chapter four.

Model Overview

It is difficult to determine a uniform transportation strategy for all North Dakota exporters. North Dakota spans approximately 70,000 land miles, meaning that a shipper along the eastern boarder of North Dakota may need to adopt a completely different strategy from shippers in the west. The network flow model developed in chapter four identifies the optimal shipping route based each point of origin; the high demand figures are strategic to ensure all points of origin are analyzed.

The model was analyzed using minimization techniques in linear programming. The goal for the base model is to replicate the current state of transportation options for North Dakota exporters. This model analyzes the minimum cost shipping route, excluding a Minot intermodal terminal, and assumes all containers are filled at the site of production. The base model is depicted by Figure 4.1.

Developing the expanded model to include sensitivity tests required a change in model structure. Most importantly, the minimum cost structure of the expanded model applies integer linear programming methods to account for the models' seventh constraint; containers leaving Minot must exit the terminal in unit train intervals. The second sensitivity test included in the expanded model accounts for a transportation strategy including a Minot intermodal terminal and takes into account empty container repositioning. This expansion of the base model can be seen by Figure 4.2.

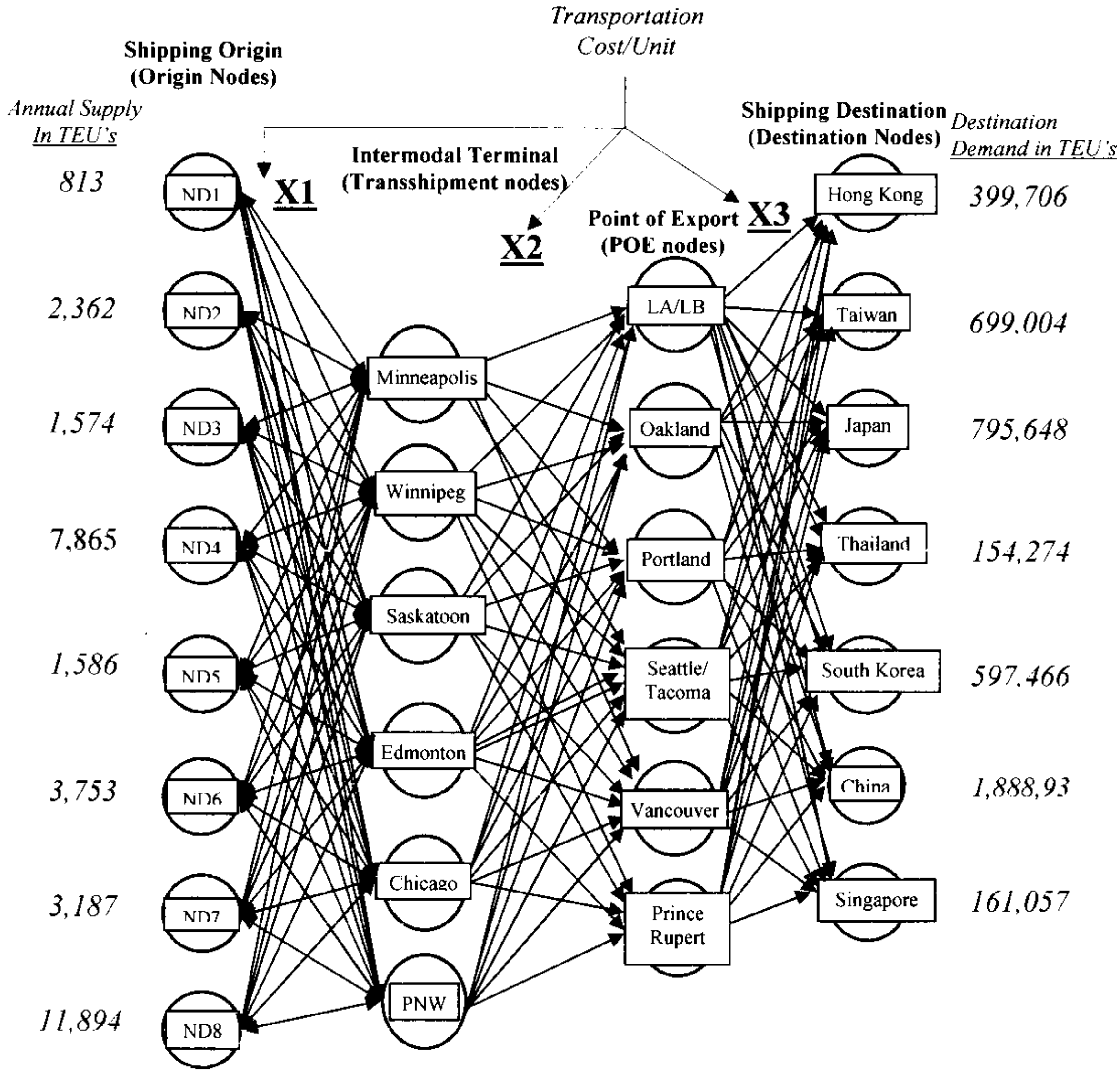

Figure 4.1 Network flow base model representation

Next, the model includes an additional sensitivity to analyze the alternative of a soft IP producer to ship by container from the site of production, or if there might be a strategic alternative. The alternative shipping method would involve a bulk truck movement to the closest corresponding elevator and a proceeding bulk rail movement from elevator to container stuffing facility. Once the single car bulk rail shipments have arrived at the point of export the product then travels across the x_6 movement being transloaded into a container and transferred to the ocean vessel for export. Figure 4.3 depicts this final expansion to the network flow model.

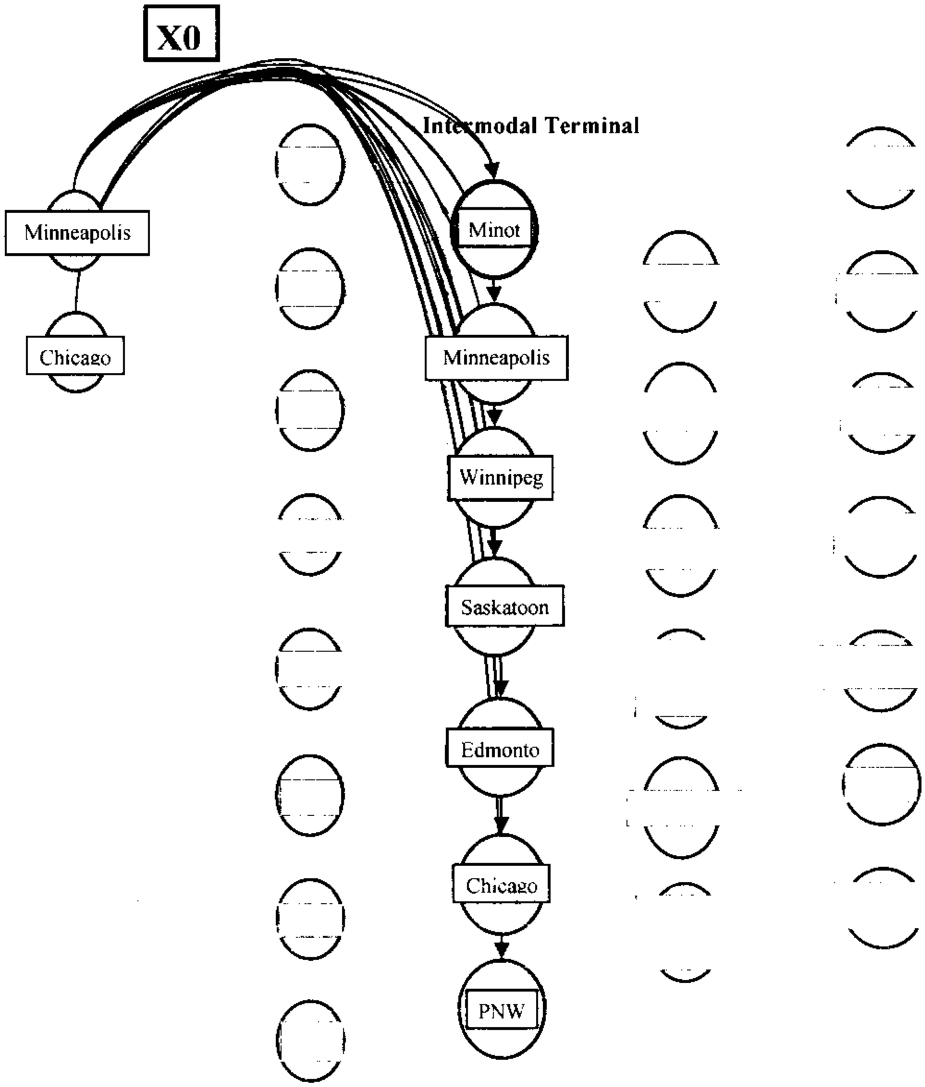

Figure 4.2 Network flow model with the inclusion of Minot and the X_0 repositioning cost

The inclusion of this sensitivity is a focal point of chapter four. It is important for North Dakota exports to think intentionally on all potential transportation options. An increase (decrease) in intermodal handling fees or increased costs for repositioning empty rail cars may cause containerized (bulk) shippers to consider shipping alternatives.

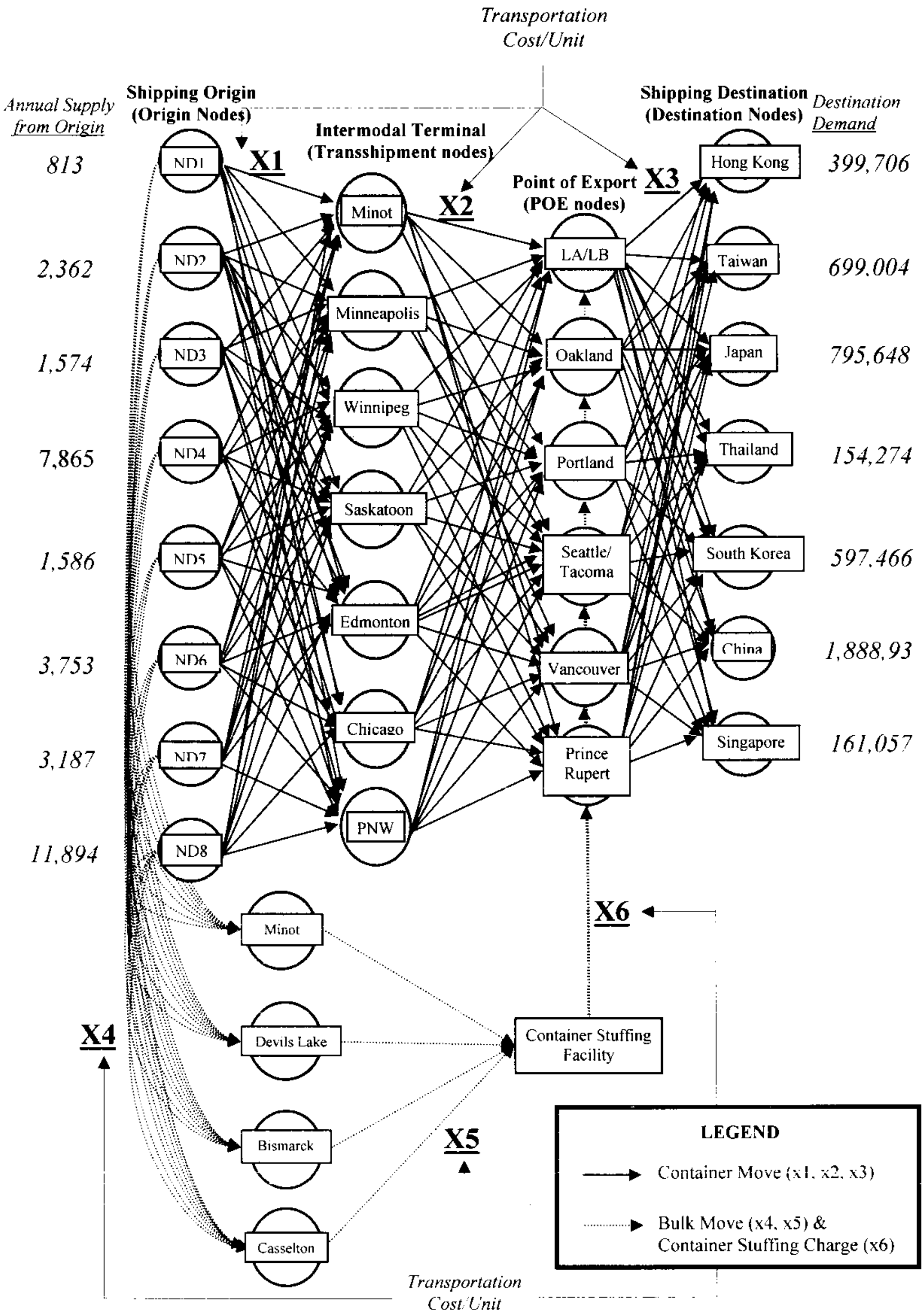

Figure 4.3 Bulk vs. containerized shipping

Model Specification

The network flow model identifies the optimal routing and logistical characteristics for container exports originating from North Dakota. Logistical functions included in the model are the movements of containers by truck, rail and ocean carrier. A second logistical option is developed to capture the potential for producers to bulk ship goods from North Dakota to a container stuffing facility adjacent to the point of export. In other words, the model analyses cost efficiency by determining the shipping option that minimizes total cost; by choosing either bulk shipments or containerized shipping from each origin. Table 4.1 outlines the cost variables contained in the model.

Table 4.1 Definition of variables

Base Model Variable	Definition of Variable	Sensitivity Variable	Definition of Variable
X_1	Cost of container movement by truck from the point of origin to intermodal terminal	X_0	Cost of repositioning empty container to intermodal terminal
X_2	Cost of container movement by rail from intermodal terminal to point of export	X_4	Cost of bulk movement by truck from point of origin to shuttle loading facility
X_3	Ocean vessel costs from point of export to final destination	X_5	Bulk rail rate from shuttle loading facility to point of export
		X_6	Cost of stuffing a container at the point of export

Objective Function

Minimize total cost=

$\sum((i,t),x_1(i,t)*r_1(i,t))+$	Base Model Objective	Expanded Model Objective Function
$\sum((t,p),x_2(t,p)*r_2(t,p))+$		

$\sum((t,p),x_2(t,p)*h_2(t))+$		
$\sum((p,d),x_3(p,d)*r_3(p,d))+$		
$\sum((i,n),x_4(i,n)*r_4(i,n))+$	Sensitivity Test Objective	
$\sum((ime,im),x_0(ime,im)*r_0(ime,im))+$		
$\sum((n,o),x_5(n,o)*r_5(n,o))+$		
$\sum((o,p),x_6(o,p)*r6(o,p))+$		

Subject to the previously outlined constraints:

$$\sum((im3),x_1(i,im3))*(21/25)+x_1(i,"pnw")+\sum((n),x_4(i,n))=Supply \tag{1}$$

$$\sum((ime),x_0(ime,t))=\sum((i),x_1(i,t)) \tag{2}$$

$$\sum((ime),x_0(ime,o))=\sum((p),x_6(t,p)) \tag{3}$$

$$\sum((p),x_2(t,p))=\sum((i),x_1(i,t)) \tag{4}$$

$$\sum((t),x_5(n,t))=\sum((i),x_4(i,n)) \tag{5}$$

$$\sum((p),x_6(t,p))=\sum((n),x_5(n,t)) \tag{6}$$

$$\sum((im3),x_2(im3,p)+x_2("pnw",p)+\sum((n),x_4(i,n))\le\sum((d),x_3(p,d)) \tag{7}$$

$$\sum((p),x_3(p,d))=Demand \tag{8}$$

$$220*U(p)-x_2("Minot",p)=0 \tag{9}$$

where

i = origin node (ND1, ND2, ND3, ND4, ND5, ND6, ND7, ND8)

t = transshipment node (Minot, Minneapolis, Winnipeg, Saskatoon, Edmonton, Chicago, PNW)

p = export node (Los Angeles/Long Beach, Oakland, Portland, Seattle/Tacoma, Vancouver, Prince Rupert)

d = destination node (Hong Kong, Taiwan, Japan, Thailand, South Korea, China, Singapore)

n = shuttle loading facility (Minot, Bismarck, Devils Lake, Casselton)

o = container stuffing facility (assumed adjacent to all "p")

ime= intermodal terminal of empty containers source

im= intermodal terminal that empty containers are repositioned to

im3= Intermodal terminals excluding PNW

r_1 = drayage rate in dollars/mile per TEUs for x_1 truck movement

r_2 = rail rate for x_2 movement from transshipment facility to point of export

h_2 = handling charges per TEU for containers at each intermodal terminal

r_3 = rate for the ocean port and sea transfer for x_3 movement

r_0 = rail rate for repositioning empty containers from source to destination

r_4 = truck cost per TEU for bulk x_4 movement by truck

r_5 = rail rate in TEUs for x_5 movement from shuttle loading facility to container stuffing facility

r_6 = container stuffing charge for the x6 movement

U = Integer variable signifying that containers leaving Minot must be in unit train intervals, or 256 rail cars.

Mathematical Descriptions:

The base model objective function is outlined by a table to indicate the equations corresponding to the base model versus those of the expanded model. It includes a set of equations to minimize the total cost of hard IP container movements from the point of origin to final destination. Hard IP products must be loaded into a container at the site of production and remain that way until the consumer receives the container. Thus, the objective function of the base model seeks to minimize the x_1, x_2, and x_3 movements (Table 4.1) and terminal handling fees. For example, the first summation equation in the base model, $\sum((i,t), x_1(i,t) * r_1(i,t))$, represents the summation of all movements from producing regions to the intermodal terminals. The latter part of the equation states that the distance, $x_1(i,t)$, from origin to intermodal terminal is multiplied by $r_1(i,t)$, the drayage rate from origin to intermodal terminal.

The expanded model objective function includes follows closely to the base model objective function. In the expanded model the sensitivities added to the objective function are minimized. This includes minimizing the total cost of the x_0, x_4, x_5, and x_6 movements (Table 4.1). The first summation equation, $\sum((ime,im), x_0(ime,im) * r_0(ime,im))$, represents the distance that an empty container has to travel from its origin to intermodal terminal (x_0) times the rate of repositioning that empty container (r_0).

Estimated supply of North Dakota's outbound containers and total demand for each destination node were important factors when considering model constraints. The network flow model is subject to nodal, arc and other miscellaneous transportation constraints. Constraints applied to the base network flow model include:

(1) Shipments from an origin to transshipment node multiplied by (21/25) to account for the weight difference containers shipped from interior markets + containers traveling by truck to the PNW (since rail restrictions are not applied, assumed load weight is equal to bulk) + total bulk shipments are equivalent to the supply of that origin;

(2) The number of filled containers exiting an intermodal terminal must equal the number of empty containers previously repositioned to that terminal.

(3) The number of filled containers exiting a container stuffing facility must equal the number of empty containers previously repositioned to that facility.

(4) Shipments into the intermodal terminals must equal total shipments exiting the intermodal terminal;

(5) Bulk shipment arriving by truck into a shuttle loading facility must equal total bulk rail shipments leaving the facility;

(6) The bulk rail shipments entering the container stuffing facility must equal the number containers exiting the container stuffing facility;

(7) Shipments from an origin to transshipment node excluding the PNW+ containers traveling by truck to the PNW (since rail restrictions are not applied, assumed load weight is equal to bulk) + total bulk shipments is less than or equal to the total shipments leaving the point of export;

(8) The total number of TEUs shipped from the point of export is equal to demand;

(9) Containers leaving Minot must leave in intervals of unit trains, or 256 rail cars.

Model Description

The network flow model is based on a cost minimization problem and is subject to supply, demand, and other related transportation constraints. The model was solved using GAMS.

Supply

The network flow model developed in this chapter is specified in twenty-foot containers (TEU's). However, the data source Berwick, et al. (2002), includes estimates for both twenty and forty-foot outbound containers; it is assumed that one forty-foot container is equivalent to two TEU's. Supply was derived from the Berwick, et al. (2002) report outlining the estimated number of outbound containers for North Dakota and parts of Montana, South Dakota, and Minnesota. "Methodology estimates the tons of various products transported from the region, multiplied by the Illinois percentages of these same products that move in intermodal truck-rail configurations providing an estimate of potential intermodal freight" (Berwick, Bitzan, Chi, & Lofgren, 2002). Table 4.2 outlines the regional estimated outbound TEU container traffic.

The demand constraint, being significantly larger than total supply of containers in North Dakota, forces all available containers to be shipped from their origin. The demand creates a pull on total estimated supply and forces all supply to travel across the network flow model.

Demand

The majority of all containers exported from the United Stated must be transshipped through Asian ports before reaching their final destination. For example, 80 to 90 percent of U.S. agricultural containers exported to China first arrive in Hong Kong (Caron, Taylor,

& Harbert, 2001). Because the network flow model does not consider transportation costs beyond the first point of foreign transshipment, the leading seven ports for agricultural imports (or points of transshipment) are analyzed to determine model demand.

Table 4.2 Estimated TEU container supply

Region	Regional Estimated Potential Outbound 20' Container
ND1	1237
ND2	3466
ND3	2257
ND4	11498
ND5	2279
ND6	5369
ND7	4442
ND8	16979
Total TEUs	**82069**

Adapted from Mark Berwick, John Bitzan, Junwook Chi, and Mark Lofgren, "North Dakota Strategic Freight Analysis, the Role of Intermodal Container Transportation in North Dakota: Executive Summary," Upper Great Plaines Transportation Institute (November 2002): 12

A total demand figure for United States containers (in TEU's) adopted from the Port Import Export Reporting Service (PIERS) at each destination node included in the model. PIERS reported data from Vessel Manifests and Bills of Lading; data from the year 2007 was applied. Demand for each destination node included in the network flow model is outlined in Table 4.3.

Table 4.3 United States export demand by trading partner

Trading Partner	2007
China	1,888,937
Japan	795,648
Taiwan	699,004
South Korea	597,466
Hong Kong	399,706
Thailand	154,274
Singapore	161,057

North Dakota's container shipment supply is less than meets the demand figures displayed in Table 4.2. Because the model is only analyzing North Dakota supply, it will always recognize an unmet demand and the model forces North Dakota's total supply to be exported, travelling through the transportation network. This is a key element to the development of a transportation strategy for North Dakota shippers. Because total supply from each origin must be shipped, the model identifies optimal shipping strategies for each of the eight regions in North Dakota.

Variables Explained

Variables included in the model identify the costs associated with exported good movements. The developed model outlines seven primary movements. These movements are outlined below by variables x_0 through x_6; the base model beginning with x_1.

The first variable of the base model, being the x_1 movement, captures transportation costs of a filled container from its point of origin to an intermodal terminal. The drayage cost of hauling a container by truck from the point of origin to an intermodal terminal is estimated to be $2 per mile.[5] Choosing the center-most city for each of the eight production regions allowed for calculating the distance from each point of origin to intermodal terminal.[6] Next, the miles from each of the eight selected cities to the surrounding intermodal terminals were calculated using the website, www.mapquest.com.

X_2, the second base model movement, captures the cost of container rail shipments from each intermodal terminal to the points of export. Rail rates were derived from the Surface Transportation Board (STB) Public Waybill, 2007 data. Figure 4.4 displays the

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[5] Truck estimate provided by industry professional Ron Martian of Midwest Motor Express, an LTL company based in North Dakota.
[6] These eight production regions are adopted from Berwick et al. (2002) and seen in Figure 2.10.

U.S. Class I Rail Networks used for exporting containers. As displayed in Figure 4.4, the BNSF is the only U.S. Class I Rail Network servicing North Dakota.

Because the STB data only reports U.S. rail data, rail rates for Canadian networks are assumed to be a function of distance and comparable to that of U.S. rail network rates. Rail rates provided by the 2007 STB data were regressed on distance to determine a distance parameter for Canadian network rail lines. Canadian rail rates are then estimated by multiplying rail miles, from the intermodal terminals to points of export, by the distance parameter achieved through regression. Figure 4.5 outlines Canadian rail networks used for the export of containers; the Canadian Pacific Railway being the only Canadian rail network to service North Dakota.

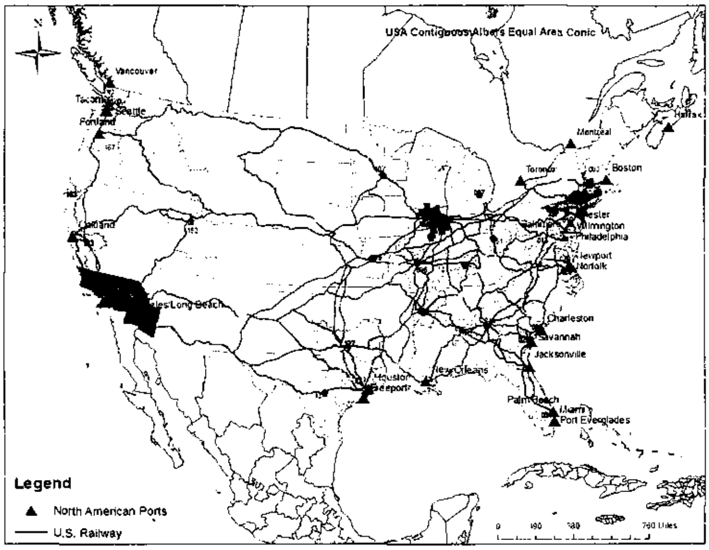

Figure 4.4 United States Class I railway networks

Adapted from Wilson, William W; Dahl, Bruce; Fan, Lei; "Task 3-Update Current Network Model and Data Toward a Global Forecast of Container Flows. Container Model and Analysis: Long Term Analysis of Infrastructure Demands and Risks," North Dakota State University (January 2010): 15.

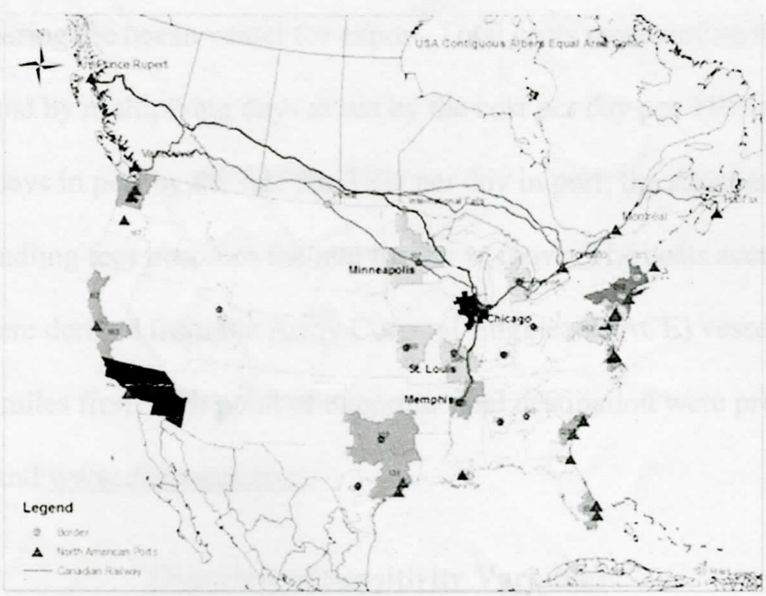

Figure 4.5 Canadian rail networks used for the export of containers

Adapted from Wilson, William W; Dahl, Bruce; Fan, Lei; "Task 3-Update Current Network Model and Data Toward a Global Forecast of Container Flows. Container Model and Analysis: Long Term Analysis of Infrastructure Demands and Risks," North Dakota State University (January 2010): 16.

X_3 captures the costs of shipping a container by ocean carrier from the point of export to final destination. Ocean shipping costs include the costs for a vessel in port and at sea. The cost per TEU per day was found by dividing the economic speed by the ocean vessels nominal TEU capacity. Similarly, the cost per TEU per day in port is found by taking the average daily vessel cost divided by the vessel's nominal TEU capacity. Lastly, the number of days at sea is a function of nautical miles and economic speed. Days at sea are found by dividing the distance from point of export to destination by the economic speed multiplied by 24.[7]

An estimated handling fee of $285/TEU is applied to total cost (Fan, Wilson, & Dahl, 2010, p. 14). It is also assumed that an ocean vessel spends five days in- port while

[7] Days at sea= Nautical Miles/ (Economic Speed (knots/hr) * 24)

loading and preparing the ocean vessel for export. Total costs representing the x_3 movement is found by multiplying days at sea by the cost per day per TEU at sea and multiplying the days in port by the rate per TEU per day in port; the summation of the two, in addition to handling fees becomes the rate for the x_3 move. The costs accumulated by ocean carriers were derived from the Army Corps of Engineers (ACE) vessel-costing model. Nautical miles from each point of export to final destination were provided by the ACE 2007 data and www.distances.com.

Overview of Sensitivity Variables

Sensitivity tests are included to expand the base model. They are included to answer the "what if" questions many ask about North Dakota's transportation potential. The sensitivity variables described in this section are all expansions to the base model; each attempts to describe various possible transportation scenarios. Variables x_0, x_4, x_5, and x_6 are defined.

One of the first sensitivities includes the Minot intermodal terminal as a shipping alternative to North Dakota exporters. Variable x_0 captures the cost of repositioning empty containers from Chicago and Minneapolis to intermodal terminals (i.e. Minot) and exporting ports. This data was derived from the 2007 STB data. The data was achieved by specifying rates for empty container moves from origin to destination. Chicago and Minneapolis were chosen as points of origin for empty containers for the following reasons. First, referring back to Figure 2.15 it is shown that the 2007 concentration of empty containers is greatest in these areas. Secondly, it makes intuitive geographical sense that any containers repositioned to North Dakota will come from either Chicago or Minneapolis.

A second sensitivity is included to capture transportation options for soft IP producers. This sensitivity represents a bulk shipment option from the point of origin to a container stuffing facility adjacent to the point of export. X_4 represents the total cost of bulk movements by truck from the point of origin to shuttle loading facility. The four elevator loading facilities, Minot, Devils Lake, Bismarck and Casselton, were chosen to correspond to a central location of the four BEA regions that encompass North Dakota.

The truck rate per mile is a formula based approach calculated using the 2007 Agriculture Marketing Service (AMS) quarterly truck rate data. The AMS data yields regional truck rate estimates allowing for analysis of truck rates within proximal distances to North Dakota production sites. The data provides truck rates from the second, third, and fourth quarters of 2007 in North Central Region of the United States. This data is used to develop the costs that represent x_4. Table 4.4 summarizes the rate per mile data for 2007 (AMS, 2007).

Table 4.4 Quarterly truck rate per mile data, 2007

North Central Region	**Rate Per Mile**		
	25 Miles	100 Miles	200 Miles
2007 Q4	4.85	2.65	2.17
2007 Q3	4.24	2.55	2.4
2007 Q2	3.95	2.41	2.05
Average	4.3467	2.5367	2.2067

***Based on 80,000 lbs gross vehicle weight limit**

As seen by the table, truck rates are based on the 80,000lb gross vehicle weight limit. Using an online conversion calculator, it was determined that 25 metric tons is equivalent to both one TEU and 55,115.56lbs. Information previously included in the model is in the units of TEUs; to be consistent with the uniformity among units, a truck rate per TEU is converted. The first step in converting data to rates per TEU was to find a relationship among the rates provided by Table 4.6. This relationship was determined by plotting the data points on an (x,y) axis and including a logarithmic line (Figure 4.6).

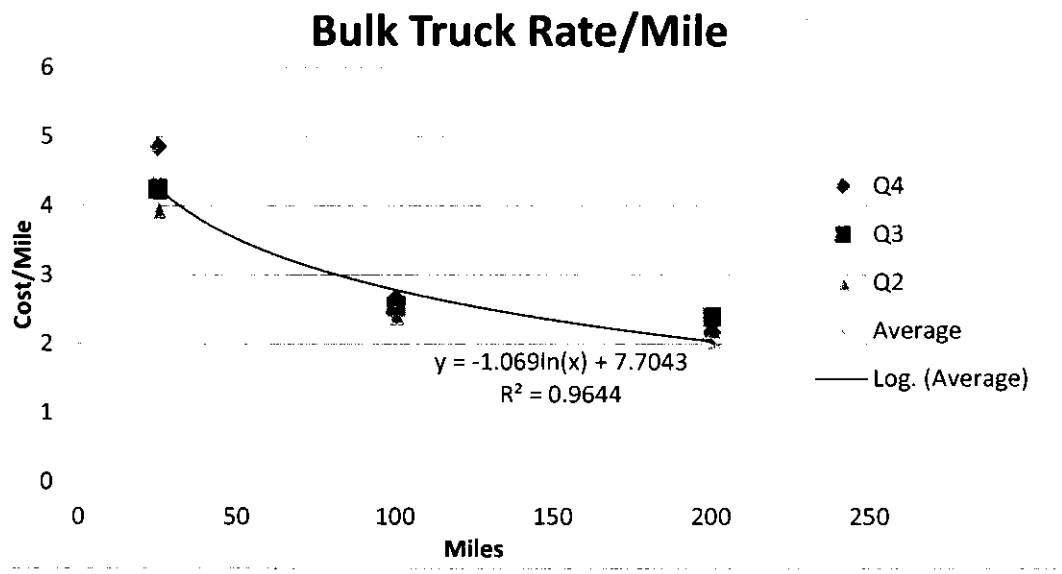

Figure 4.6 Observed relationships among bulk truck rates per mile

The relationship among truck rates is shown in Equation 4.1.

$$y = -1.069\ln(x) + 7.7043 \tag{4.1}$$

The y variable is the truck rate per mile and x represents miles per trip. To achieve trip rates (i.e. rate for trip originating from ND1, or Williston, and traveling to the shuttle loading facility in Bismarck) Equation 4.1 is multiplied by trip miles, yielding Equation 4.2. The mileage from each of eight production regions to shuttle loading facilities was determined by www.mapquest.com.[8]

$$(y = -1.069\ln(x) + 7.7043) * x \tag{4.2}$$

These rates were converted from the 80,000lb truck to TEU is made. Assuming that 26,000lbs of the 80,000lb gross truck weight consists of truck weight, a net weight for

[8] Miles associated with the four regions that contain bulk loading facilities have an assumed mileage of 50 miles to elevator.

goods transferred is assumed to be 54,000lbs.[9] The net weight in pounds is then divided by the 55,115.5lbs that make up one TEU.[10] One TEU is equivalent to 98% of an 80,000lb truck. The rate conversion (Equation 4.3) divides Equation 4.2 by 82% to achieve a rate per TEU.

$$Rate / TEU = ((y = -1.069 \ln(x) + 7.7043) * x) / 0.82 \qquad \textbf{(4.3)}$$

The second transportation strategy developed includes a rail bulk shipment from the four outlined bulk loading facilities to the points of export. The single car rail bulk shipment rate from loading facility to container stuffing facility is captured by variable x_5. These rail rates were again derived from the 2007 STB data. Similar to the container rail rates derived by STB data, regression analysis was applied to the U.S. rail rates for determining the single car bulk rates for Canadian rail networks.[11] Rates determined by regression include all transfers terminating at Vancouver and Prince Rupert.

The weight of a single car bulk shipment is assumed to be 90 metric tons. Thus, one single car bulk shipment is equivalent to 3.6 TEUs at 25 metric tons each. To convert the single car bulk movement from 90 metric tons into TEUs, the model is specified to divide rail rates by 3.6 to achieve the rate per TEU.

A preceding movement to the container stuffing facility for transloading the bulk product into containers for export is represented by the variable x_6. The container stuffing facility is assumed to be adjacent to each port of export, thus a transportation fee is not applied. The x_6 variable captures the cost of stuffing a container at the ocean port rather

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[9] 80,000lbs - 26,000lbs = 54,000lbs
[10] 54,000lbs / 66,138lbs = .82
[11] Assuming rates are a function of distance

than on the farm. It is estimated that the rate of transloading a container at the port is $300/container.[12]

This practice of bulk shipment and transloading at the point of export is becoming increasingly popular and should be considered for North Dakota producers. However, it must also be noted that some producers do not have the bulk transfer option due to consumer quality demands as discussed in Chapter two.

These seven variables represent model costs. The data sources and assumptions conferred throughout the explanation of variables are summarized by Tables 4.5, 4.6 and 4.7.

Data Summary

Table 4.5 Model assumptions

Variable	Corresponding Assumption
X_1	The distance from center-most city for each of the eight origins to intermodal terminal is the mileage for each production regions to intermodal terminals
X_2	Filled container rail rates for Canadian networks are assumed a function of distance and derived from the U.S. rail network rates.
X_3	An ocean vessel spends five days in- port while loading and preparing the 8000 TUE capacity ocean vessel for export.
X_4	Chosen elevators located at Bismarck, Minot, Devils Lake, and Casselton are the assumed as the choice elevators for all soft IP, or bulk shippers
X_5	Single Car rail bulk rates for Canadian networks are assumed to be a function of distance and comparable to that of U.S. rail network rates.
X_6	Container stuffing facility is located adjacent to ocean ports and no fee is applied for transferring filled containers from the stuffing facility to ocean vessel

[12] Estimation provided by Tim Woods, North Dakota Port Services

Table 4.6 Data sources and assumptions outlined

Variable	Data Source
X_1	Midwest Motor Express & www.mapquest.com
X_2	Surface Transportation Board (STB) Public Waybill, 2007 data for filled container rates
X_3	Army Corps of Engineers (ACE) 2007 vessel-costing model & www.distances.com
X_0	Surface Transportation Board (STB) Public Waybill, 2007 data for empty container rates
X_4	2007 Agriculture Marketing Service (AMS) quarterly truck rate data & www.mapquest.com
X_5	Surface Transportation Board (STB) Public Waybill, 2007 data for filled single car bulk rates
X_6	BNSF

Table 4.7 Estimations assumed in the model

Variable	Cost Estimation	Data Source
X_1	\$2/Mile; container dray rate	Ron Martin, Midwest Motor Express
X_2	\$100/TEU; Minot terminal handling fee	Tim Woods, North Dakota Port Services
X_3	\$285/TEU; export port handling fee	(Fan, Wilson, & Dahl, 2010)
X_6	\$400/TEU; transloading fee	Jonathan Long, BNSF

Summary

Chapter four developed the linear programming techniques used for solving the cost minimization network flow model. Cost variables have been defined, three of which are included in the base model and remaining four variables included as the model is expanded. An integer variable is added to the expanded model to account for the unit train container intervals leaving the Minot terminal.

Model results determine the optimal shipping mode and route by considering minimum cost. The pull created from high demand figures forces the total estimated supply to travel through the transportation network; because demand is greater than supply, the model will always recognize an unmet demand and will force total supply to be shipped. Finally, sensitivity tests are conducted to determine:

- How transportation strategies change when a bulk shipment option is included in the base model;
- How transportation strategies change with the inclusion of a Minot, ND intermodal terminal;
- Examining an environment in which both options of shipping by container and bulk shipping are available to North Dakota exporters;
- How model results are effected when considering interior ports can only load 21 metric ton TEUs while the bulk option transloads into 25 metric ton TUEs ;
- Finally, sensitivity tests to the expanded model are conducted.

CHAPTER V. RESULTS

Results from the base case and sensitivity analysis are presented in this chapter. Chapter four is organized into four sections. Section one presents the optimal solutions for shipping in today's transportation environment; also known as the base case model. Section two illustrates model results when sensitivities are added. Section three provides results from sensitivities applied to the expanded model. Section four introduces cooperative game strategies and incorporates model results to develop and analyze cooperative play among key market players.

Base Case Results

The base case aims to replicate the current transportation options available to North Dakota exporters. The base model seeks to minimize the costs included by the x_1, x_2, and x_3 variables. This model assumes producers are all shipping hard Identity Preserved (IP) products, stuffing containers are at the site of origin, and excluding the Minot intermodal terminal and a bulk shipping option, thus, it represents today's transportation environment. Figures 5.1 and 5.2 regionally display the transportation path that minimizes network flow costs of the base model.

The drayage costs represented by the x_1 variable were calculated by looking to the central-most city of each region. Drayage costs can account for up to 40% of total transportation expenses. Thus, network flow results are largely dependent on drayage costs. Because the model analyzes by region and not by individual production site, the regional estimation may not accurately represent every production site within the region.

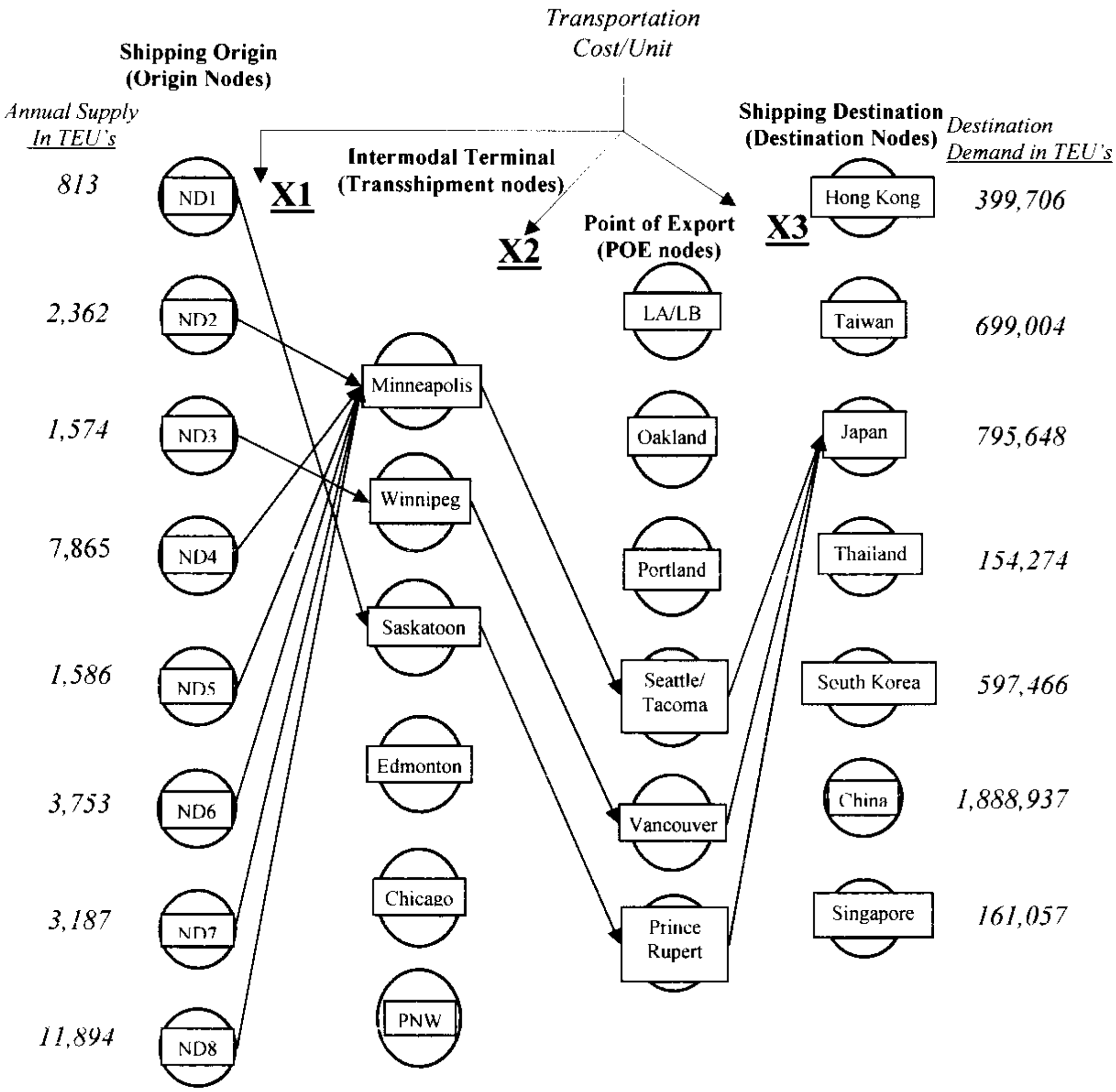

Figure 5.1 Regional network flow base case model results; assuming all containers are stuffed at the site of production

Results indicate hard IP producers in North Dakota realize minimized costs by draying containers to the intermodal terminals of Saskatoon, Winnipeg, or Minneapolis. Goods shipped to Saskatoon go to Prince Rupert by rail, goods shipped to Winnipeg travel by rail to Vancouver, and finally, goods out of Minneapolis shipped by a rail to Seattle-Tacoma.

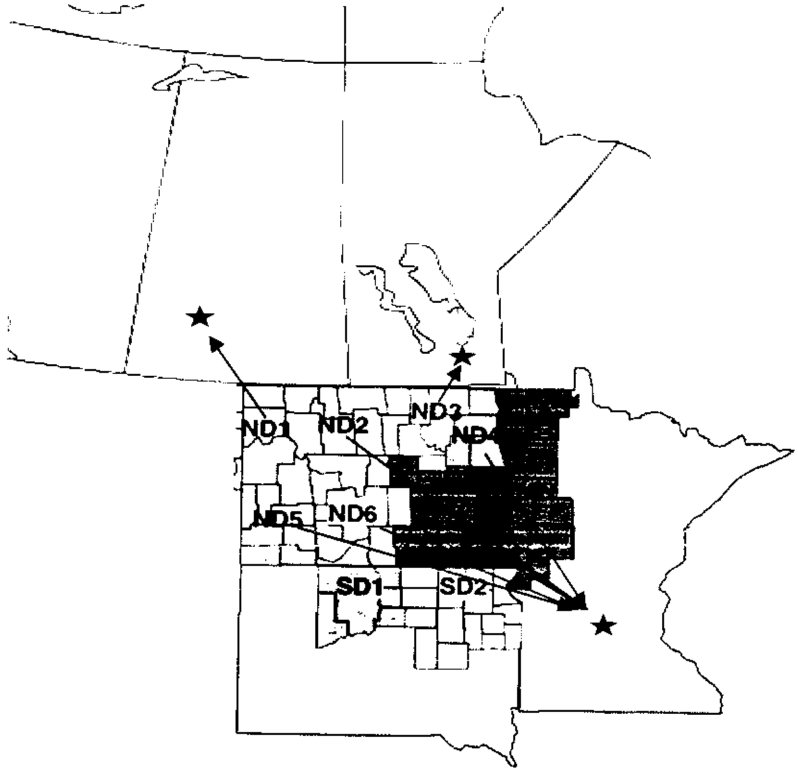

Figure 5.2 Regional map of base case model results; assuming all containers are stuffed at the site of production

For example, looking to region ND4, producers in the northern-most portion of this region could more likely utilize the Winnipeg intermodal terminal rather than Minneapolis. However, because the miles were estimated from the center of ND4, the model chooses Minneapolis as the most cost efficient shipping route. As a general rule, the regional results do represent the whole, but some exceptions such as this may apply.

Reduced Costs

To determine which regions need to consider alternative shipping routes, reduced costs were derived by model results are examined. Reduced costs, observed in dollars, illustrate how much a variable has to change before it becomes part of the solution. To start, x_1 reduced costs are observed; following are the reduced costs for x_2 and x_3.

When considering the reduced costs of x_1 (drayage from origin to intermodal terminal) it is important to note that regions ND1, ND5, ND6, ND7, and ND8 will not considered for alternative shipping routes. This can be determined by looking to the reduced costs of the closest shipping alternative. Regions not considered for alternative shipping routes are determined by looking to the closest shipping alternative. For regions not considered, reduced costs are significantly higher than the optimal solution; signifying a true optimum is displayed by model results. However, given reduced costs less than $150 for alternative routes in regions ND2, ND3, and ND4 are examined. Table 5.1 displays reduced costs derived from the base model.

Table 5.1 Base model reduced costs for x_1 drayage movement

Origin	Destination	Reduced Cost
ND2	Winnipeg	$113
ND3	Minneapolis	$31
ND4	Winnipeg	$45

ND2, located in north central North Dakota, realizes ships to Minneapolis. Looking to the geographic position of ND2, it makes intuitive sense that Winnipeg should also be considered as a shipping alternative. This seems especially true for producers in the north eastern corner of the region. The model reduced cost provides that for the x_1 variable to consider shipping from ND2 to Winnipeg, total shipping costs need to be reduced by $113 before being considered a shipping solution. This was calculated at $2/mile for a round trip, thus it can be determined that a production site approximately 28 miles closer to Winnipeg, from the regional center of ND2 should also consider shipping to Winnipeg a cost minimizing strategy.

Regions ND3 and ND4, located in the northeast corner of North Dakota also have shipping alternatives. For region ND3, Winnipeg is the current shipping solution. The reduced cost associated with shipping to Minneapolis from ND3 is $31. In other words, if shipping to Minneapolis was reduced by $31, it would become an optimal alternative for ND3's exports. ND4 has Minneapolis as the shipping solution that minimizes total costs. The model also has a reduced cost of $45 for shipping to Winnipeg. This reduced cost suggests ND4 might also consider shipping to Winnipeg alternative to shipping through Minneapolis. Next, the reduced costs for x_2 movements in the base case are seen in Table 5.2.

Table 5.2 Base model reduced costs for x_2 interior rail movement

Origin	Destination	Reduced Cost
Minneapolis	Portland	$330
Winnipeg	Prince Rupert	$255
Saskatoon	Prince Rupert	$25

For all x_2 movements originating in Minneapolis, the cost minimizing solution provides that rail shipments travel to Seattle-Tacoma. The next closest alternative is to ship from Minneapolis to Portland, OR. The reduced costs associated with shipping to Portland rather than Seattle-Tacoma is approximately $330. This is a large reduced cost.

Shipments originating from Winnipeg ship to Vancouver as the cost alternative route. For Winnipeg, shipments traveling to Prince Rupert are the closest cost alternative route having a reduced cost of $255. Finally, the cost of shipping from Saskatoon to Prince Rupert and Saskatoon to Vancouver varies by $25. The model has chosen shipments originating in Saskatoon to ship to Prince Rupert. However, assuming rail rates are accurately estimated, the reduced cost for shipping to Vancouver should also be considered a viable rail movement.

Lastly, all shipments travelling across the x_3 movement travel to Japan. Because the model has no restrictions on the number of TEUs needed at each destination, and given that demand for each destination is greater than total North Dakota supply, the model always chooses the shortest distance route. Thus, the model always chooses shipping to Japan over other destinations due to Japan's proximity to North America's west coast.

It is important to note that other shipping destinations are not much different to those captured by the base case when considering cost minimization. For ocean shipments leaving Seattle-Tacoma, four other destinations have reduced costs within forty dollars of shipping to Japan. This, also true for ocean shipments leaving Vancouver and Prince Rupert, the x_3 reduced costs for the base model's x_3 move are outlined by Table 5.3.

Table 5.3 Base model reduced costs for x_3 ocean vessel movement

Origin	Destination	Reduced Cost
Seattle-Tacoma	South Korea	$5.94
Seattle-Tacoma	China	$21.08
Seattle-Tacoma	Taiwan	$29.55
Seattle-Tacoma	Hong Kong	$38.18
Vancouver	South Korea	$4.98
Vancouver	China	$20.12
Vancouver	Taiwan	$28.59
Vancouver	Hong Kong	$37.30
Prince Rupert	South Korea	$6.29
Prince Rupert	China	$21.29
Prince Rupert	Taiwan	$29.76
Prince Rupert	Hong Kong	$38.77

In practice, shippers first consider market demand and then begin developing a shipping strategy. For example, when a North Dakota shipper makes a sale in Thailand, having a minimized cost strategy that sends the product to Japan is meaningless. Looking to the reduced costs allows form an educated cost estimation for shipping to alternative destinations.

Minot Shadow Price

The base model was modified to allow one container shipment through Minot to the ocean port. This allows for the estimation of the Minot terminal shadow price. The objective function values of the base model and the modified model, allowing for one unit shipped through Minot, were compared. It is determined that allowing one unit through Minot will reduce the objective function value by $1768.

Sensitivity Analysis

Sensitivities were applied to answer "what if" questions related to North Dakota transportation. The goal of this section is to expand the base model, applying one sensitivity at a time, until the model represents a fully expanded set of scenarios for North Dakota exporters. The first is the option for soft IP shippers to ship by bulk from one of the four selected elevator loading facilities in North Dakota. Shippers choosing this alternative to containerized shipping transfer goods across the truck and rail movements by bulk, then transload goods into a container at the point of export.

Next, the bulk shipping option is removed and Minot is introduced as an operational intermodal shipping facility. This test includes a cost for repositioning empty containers to Minot. Subsequently, while analyzing Minot, the option of single car bulk shipment to port is reapplied to the Model; and the two tests are examined simultaneously. This combination of the sensitivities is crucial to soft IP producers having an option to choose container shipping out of Minot versus bulk transport. The final sensitivity relates to a specific constraint applied to the Minot intermodal terminal.

Due to rail weight restrictions, containers shipped from interior intermodal terminals have a limited capacity of 21 metric tons. In comparison, containers shipped by bulk to a container stuffing facility adjacent to the ocean port have the ability to load containers at 25 metric tons. This creates the need to apply a sensitivity capturing the cost difference associated with load weights.

Base Model Including Bulk Shipment Sensitivity

The first sensitivity test allows for cost of shipping by bulk to the point of export versus the requirement to loading containers at the site of production. In this case, rail cars are shipped to port and containers are then stuffed at the ocean port. This option is consistent with the base model, adding a bulk shipment sensitivity test. The model results display bulk shipping as the most cost efficient option for soft IP producers in five of North Dakota's eight production regions.

Model results for this first sensitivity including the bulk rail option are depicted in Figure 5.3.

Results show that for the three regions encompassing the eastern border and southeast corner of North Dakota (ND4, ND7 and ND8), stuffing containers at the site of production remains the cost minimizing solution. However, for all other regions, the model has bulk shipments to the port and stuffing goods into a container at the port.

Unlike the base model, reduced costs do not provide a number of alternatives to sensitivity model results for consideration. However, the reduced cost of the x_4 and x_5 moves, having reduced costs less than \$50, are noteworthy. Production sites in region ND1 should consider a truck haul to the Bismarck elevator loading facility versus Minot.

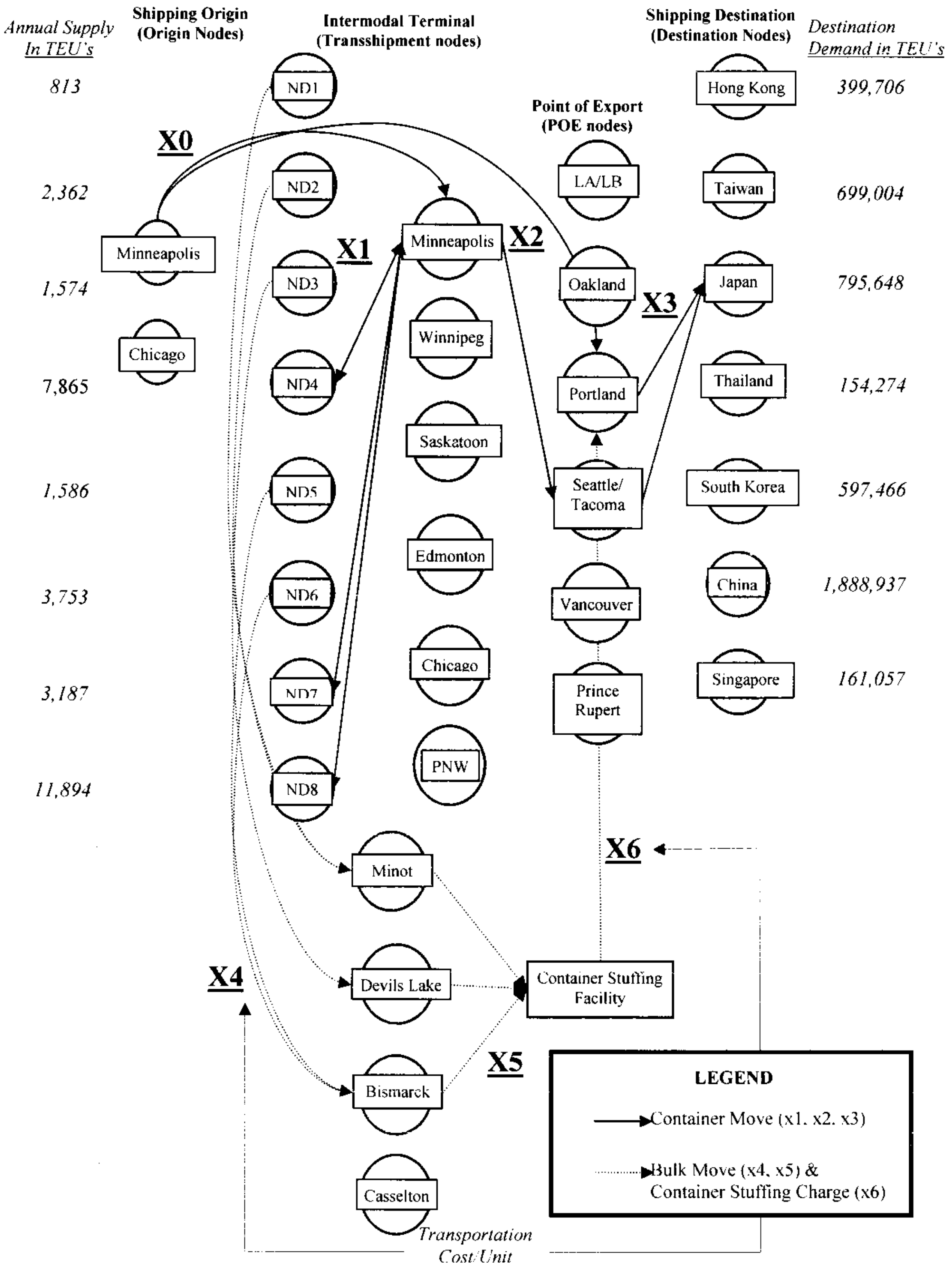

Figure 5.3 Model results for base case including bulk shipment sensitivity

Results for the x_5 move currently ship all bulk goods by rail to a container stuffing facility in Portland. Reduced costs provide shipping bulk rail from Minot to Seattle-Tacoma and Devils Lake to either Vancouver or Prince Rupert should also be considered cost minimizing options.

Base Model Including Minot

Sensitivity two forces all shipments as hard IP and includes the Minot intermodal terminal. Meaning, all goods are shipped by container from the point of origin and analyzed the cost minimizing route for each origin, including a Minot terminal as a transshipment option. This model realized an operational Minot terminal to be an important shipping option for North Dakota as seen by Figure 5.4.

Seven of the eight producing regions send at least a portion if not total volume through Minot. With the exception of goods in region ND8, Minot is the cost minimizing strategy the majority of North Dakota's volume. Region ND7 ships a small portion of goods through Minneapolis while ND8 realizes Minneapolis as the cost-minimizing route for total volume.

Berwick et al. (2002) argues that the majority of the North Dakota volume originates from region ND8. Thus, being that Minneapolis is the more competitive transportation option for region ND8, a significant portion of this regions volume would be unable to utilize a Minot facility. Although it is true that region ND8 ships the majority of its goods through Minneapolis, the model displays that ND8 goods shipped through Minneapolis account for approximately 35% of North Dakota's total supply. Excluding this

35% from total supply provides that total TEU volume remains able to support just under two unit trains per week.[13]

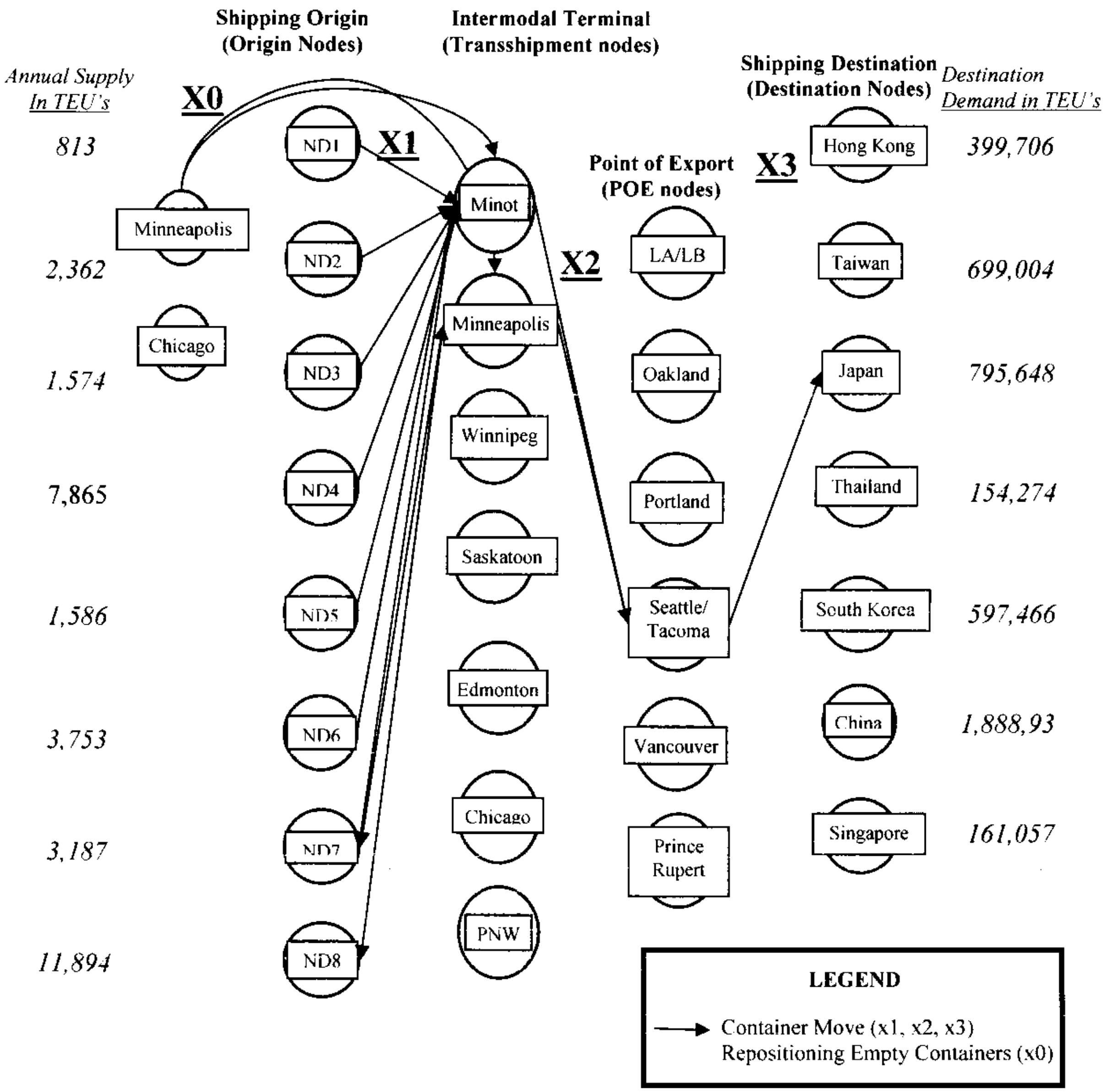

Figure 5.4 Model results for base case including a Minot intermodal terminal

The model produces results similar to the base model for the x_2 and x_3 moves. Results display shipping all rail movements from Minot or Minneapolis to Seattle-Tacoma

[13] Total Supply (32,196))* Percent volume shipped via Minot (.65)/ TEUs per unit train (220)/ Number of weeks in a year (52) = 1.8 unit trains per week

and continue by ocean to Japan. Reduced costs do not provide significant alternatives to these model results. However, it is important to note the reduced cost of the x_1 move originating from ND8. Currently, the model realizes minimized costs by draying containers round trip to Minneapolis. Model results outline draying containers to Minot as the closest cost minimizing alternative to Minneapolis at a reduced cost of $596. This leads to the conclusion that costs would need to be reduced by $596 per TEU for ND8 to consider Minot a cost minimizing solution.

Base Model Including Bulk Shipment and Minot Intermodal Terminal

Results for sensitivity three include both Minot and the bulk shipping option yield the same results as the previous model excluding the bulk shipment option. This provide that North Dakota producers will always choose to ship by container. Shipping by container from Minot is the cost-minimizing route for seven of North Dakota's eight producing regions; ND7 continuing to utilize the Minneapolis terminal for a small portion of regional volume and ND8 shipping total volume through Minneapolis. Reduced costs do not provide significant alternatives to the optimal solution.

Expanded Model Accounting for Load Weight Differences

All rail carriers including the BNSF have rules on load weight limitations. Each intermodal railcar has gross weight limits and carriers are required to stay within that limit by restricting container weight. The limitation placed on a containers' load weight moving by rail is 21 metric tons per TEU. Soft IP producers shipping bulk to the point of export and transload grains into a container are generally loading containers at 25 metric tons per TEU.

To account for these weight differences, costs for containers shipped from interior container terminals must be inflated to meet TEU demand. In other words, it takes a larger number of containers originating from interior terminals loaded at 21 metric tons per TEU to equal the shipping units traveling across the x_6 movement from container stuffing facility to port loaded 25 metric ton units. Figure 5.5 displays the network model of this expanded model.

The addition of this adjustment slightly changed results from the previous two models. Once the weight difference for shipping by bulk versus container had been accounted, region ND4 realized a bulk shipment option to provide the cost minimizing solution for 28% of regional volume. Being ND4 is the only region utilizing the bulk shipment option, all other regions followed previous shipping patterns with the exception of ND7 now shipping total volume through the Minot terminal. ND8 continued utilizing Minneapolis for total production volume.

Tests to the Expanded Model

The network flow model is now fully expanded and a need is presented to ask "what if" questions specific to this final model. The specific questions asked in this section are related to empty container repositioning cost, transloading costs at the ocean port, and Minot's terminal handling fees. This set of sensitivity tests examine how these three costs effect model solutions and will be useful for determining cooperative play in the following section of chapter five.

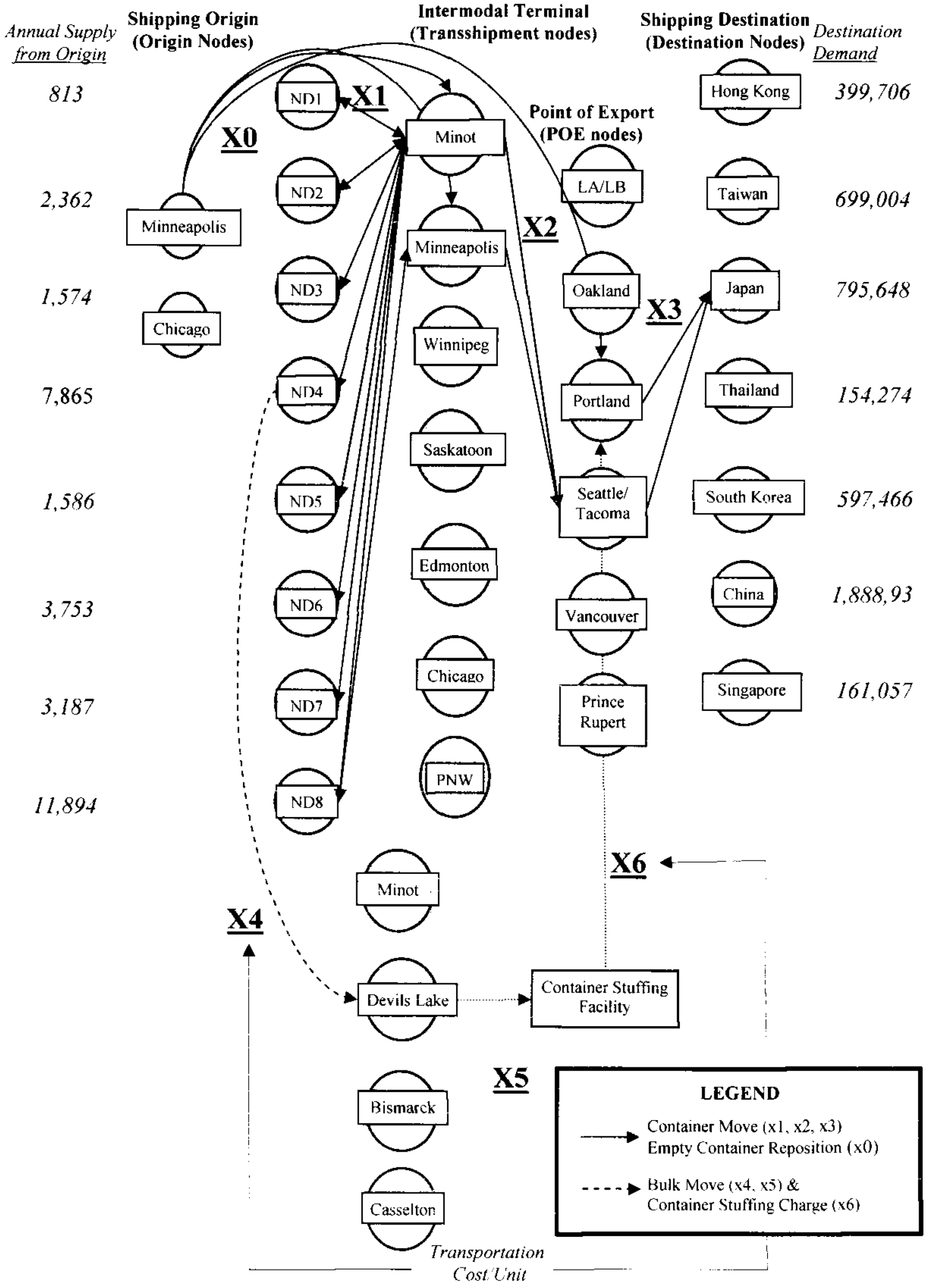

Figure 5.5 Expanded network model results for North Dakota's eight shipping regions

Cost of Repositioning Containers

The cost of repositioning empty containers from Chicago rather than Minneapolis (represented by base model) was examined to determine the costs differences of repositioning equipment across a greater distance. In Figure 2.15 it is apparent that the number of empty containers located in Chicago far exceeds all other locations. As a result, North Dakota often has to compete for the limited supply of empty containers in Minneapolis. Thus, the question is asked, what if North Dakota exporters can't get a container from Minneapolis and are forced to reposition empty containers from Chicago. In this case North Dakota exporters have to incur the cost of repositioning containers from Chicago to shipment origins. Derived from STB Waybill data, it is determined that the cost of repositioning a container from Chicago to Minot is increased by $82 per TEU from the cost of repositioning empty containers from Minneapolis.

This sensitivity test on the expanded model was conducted by attaching a rail repositioning rate to empty containers repositioned from Minneapolis to North Dakota. Attaching large rail repositioning rates eliminated Minneapolis from the minimization model's optimal solution, forcing all empty containers to be repositioned from Chicago. Empty rail repositioning is depicted by the x_0 move.

Results show that 57% of North Dakota volume continues shipping by container from origin to destination regardless of increased costs accrued by repositioning empty containers from Chicago. This estimation is reduced from the 93% choosing to ship by container when empty containers are repositioned from Minneapolis. It is concluded that 43% of North Dakota total volume is highly sensitive to the costs of repositioning empty containers.

Under the assumption that containers must be repositioned from Chicago, the model also concludes that region ND4 will continue shipping 28% of regional volume by bulk in addition to ND8 shipping total volume by bulk rather than container. However, model reduced costs provide that if shipping by container to Minneapolis were to be reduced by $30, it would once again be considered the cost minimizing solution. Provided such a small reduced cost, results are not significantly different from those having repositioned empty containers from Minneapolis.

Intuitively it seems a greater number of regions would choose to ship by bulk under these assumptions that repositioning costs are increased. Other notable reduced costs are found by looking to results for the bulk truck move. Most significantly, the model provides a reduced cost of $5 for region ND7 to ship bulk out of the Bismarck elevator loading facility. Other results conclude that region ND8 might consider shipping by bulk as a third alternative to shipping by container, or to the current solution of shipping bulk from Casselton. Other regional reduced costs are estimated to be quite large concluding that the optimal solution is displayed by model results.

Port Stuffing Fee

This sensitivity seeks to determine how changes in transloading fees at the port affect shipping patterns. Sensitivities were conducted by increasing and decreasing port stuffing costs and observing the shipping patterns. The expanded model assumes $400 per TEU as the base rate. When rates were increased from this cost a change was not seen, however, as rates were decreased shipping patterns shifted toward bulk shipping.

See Figures 5.6 and 5.7. North Dakota's sensitivity to the cost of transloading grains from covered hopper to container at the point of export. Figure 5.6 represents the expanded model assuming containers are repositioned from Minneapolis, whereas Figure 5.7 assumes containers must be repositioned from Chicago.

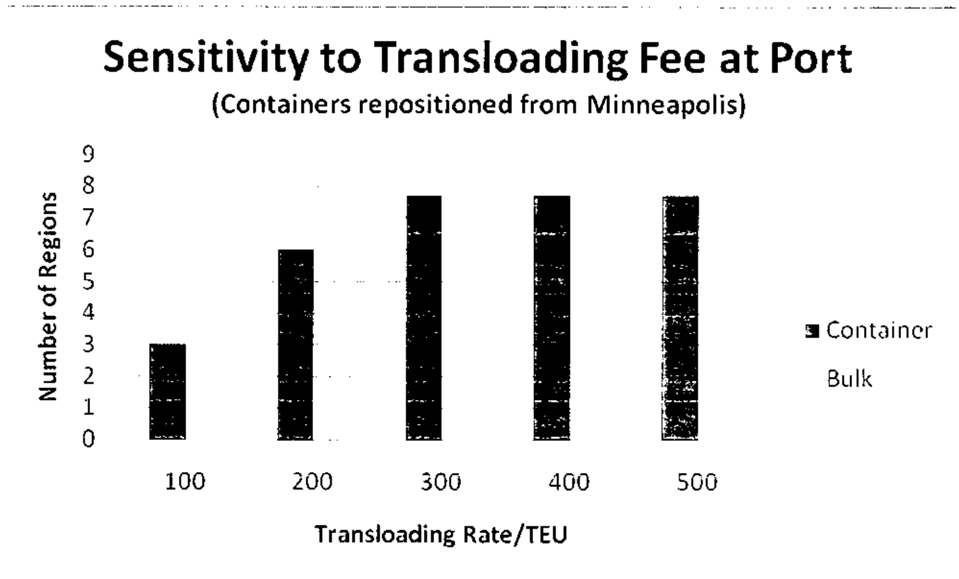

Figure 5.6 North Dakota's sensitivity to the transloading fee at point of export

According to Figure 5.6, if the transloading fees were to drop to \$100 per TEU from \$400 per TEU, five of North Dakota's eight shipping regions would realize bulk shipping to generate the cost minimizing solution. This sensitivity analysis displays a sharp decline in number of regions shipping by bulk after increasing this rate from \$100. The expanded model assumes a transloading fee of \$400/TEU and results in approximately 6% of total volume realizing bulk shipping as the cost minimizing solution. This estimation is increased to 42% assuming shippers overall costs are increased by reposition containers from Chicago rather than Minneapolis (Figure 5.7).

Figure 5.7 shows similar results to Figure 5.6. However, the results that consider repositioning containers from Chicago create a more consistent decreasing trend in bulk shipping demand than those seen in Figure 5.6.

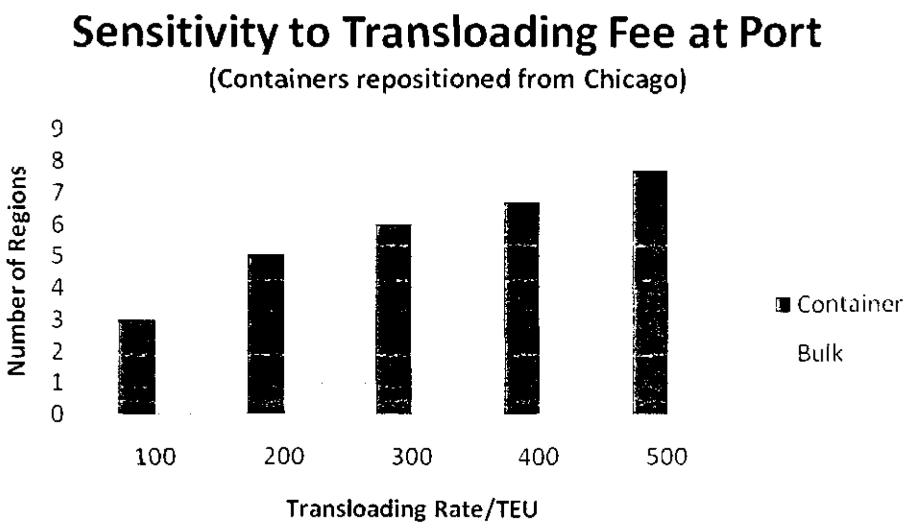

Figure 5.7 North Dakota's sensitivity to the transloading fee at point of export (containers repositioned from Chicago)

Increased repositioning costs of the x_0 will cause shippers to look to alternative shipping options. In the case of North Dakota, many shippers currently realize bulk shipping as the cost minimizing solution due to an idle Minot terminal. Similarly, considering an operational Minot, the origin from which empty containers are repositioned will create a shift in demand for alternative shipping solutions; i.e. bulk shipping.

Minot's Port Handling Fees

The final sensitivity outlines Minot's synthetic demand curve. For Minot, it is important to know how shifts in handling fees affect demand. If Minot is able to capture greater demand by lowering handling fees it might be in their interest to do so. The alternative is also true, if Minot is able to increase rates without losing customers, increasing handling fees should be considered.

The process for conducting this sensitivity test was similar to that of testing container stuffing fee sensitivities. Handling fees were increased and decreased from the expanded models assumed rated of $100 per TEU. Results were observed and can be seen by Figure 5.8, displaying Minot's synthetic demand curve.

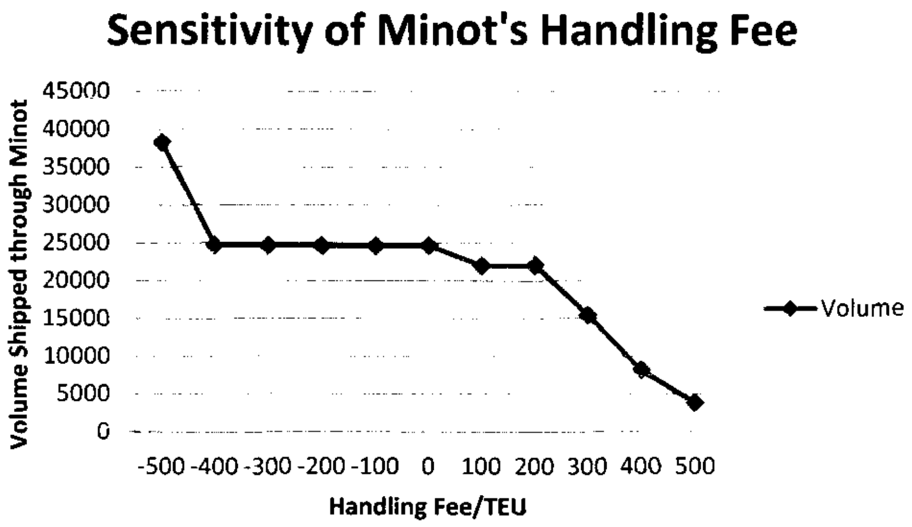

Figure 5.8 Sensitivity to Minot's port handling fee

Figure 5.8 ranges from a negative five hundred dollars to a positive five hundred. One of Minot's biggest hindrances is the need for consistent volume; without it, Minot will fail. As earlier stated, Minot is currently loosing 35% of North Dakota container supply to Minneapolis and approximately 6% to bulk transportation. If Minot can find a way to capture the additional 42% to North Dakota's total supply their chances for success are increased.

The logic for analyzing negative port handling fees comes into play in the next section and the Brandenburger & Nalebuff (1996) idea of paying customers to play. Minot's synthetic demand curve displays a consistent demand between $100 and positive $200 per TEU handling fee. The base model assumes a handling fee for Minot of $100 per TEU. However, model results conclude that Minot could increase handling fees by $100 and maintain consumer demand.

Summary

In summary, Minot is a beneficial shipping option for all but region ND8. The weight restrictions limiting interior container loads yield an advantage to the bulk shipping option. However, the model indicates that total volumes shipped by container is not significantly impacted; the model chooses to ship 94% of volume by container regardless of the inflated costs.

This estimation declines sharply when considering the first sensitivity test to determine how repositioning containers from Chicago affects shipping patterns. As total costs increased, bulk shipping gained a 36% market share, capturing 42% of total volume. A sensitivity test was conducted to examine how a shift in port transloading fees affects model results. The model determined sharp decrease for rates greater than $100 per TEU. When considering increased costs for shipping a container were accrued from repositioning equipment from Chicago, the decreasing trend of bulk shipments was more consistent, having a steady decrease.

Finally, the sensitivity test conducted to determine Minot's synthetic demand curve provided consumer demand for each corresponding rate. This information, model results, and other sensitivity tests conducted are applied to game theory in the following section.

Applications of Game Theory

The goal for this section of chapter five is to apply the model results to a game theoretic model determining the added value of each sensitivity test. To achieve this, the objective function derived by GAMS is used to analyze the total costs of each model. Table 5.2 displays model objective functions, added value of each sensitivity applied to the base model, and a surplus value achieved under cooperative operation.

The goal of determining added values is to provide negotiation power. The added value multiplied by volume is known as the model savings. Savings are distributed to pay intermodal and network operators to play. Due to limited volume, it is not in the interest of network operators to service North Dakota. Determining model savings provides negotiation power to North Dakota exporters by attaching a value to how much should be spent on creating an incentive for network operators to service the state. In the event model savings exceed this amount, Minot should then consider how to allocate additional resources to subsidize intermodal operators who otherwise ship through Minneapolis, capturing greater volumes.

Table 5.4 displays four columns. The first column defines each model examined. The second column defines the objective function value. The model objective function is the minimized shipping cost for North Dakota's total supply to travel from origin to destination. The objective function decreases as sensitivities are applied to the model until accounting for container weight restrictions of the expanded model; in this case an objective function increase relative to previous sensitivities is observed.

The third column displays each model's corresponding rate per TEU, found by dividing the objective function by total supply. Similar to the objective function column, the rates per TEU are decreased until reaching the expanded model.

Column four applies the Brandenburger & Nalebuff (1996) concept of added value. The added value represented by Table 5.4 can also be described as the saving per TEU of each sensitivity result in comparison to the base model. This value was derived by subtracting the containers rate per TEU of each sensitivity from the base case results for container rates per TEU. Added value, being the size of the pie when a sensitivity test is added to the game minus the size of the pie without that particular sensitivity, follows closely the definition described in chapter three.

Table 5.4 Added value of sensitivity models

	Objective Function	Rate Per TEU	**Added Value**
Base	$ 75,100,700	$ 2,333	
Base + Bulk	$ 72,432,139	$ 2,250	**$ 83**
Base + Minot	$ 61,136,549	$ 1,899	**$ 434**
Base + Bulk + Minot	$ 61,136,549	$ 1,899	**$ 434**
Base + Bulk + Minot + Limited Weight (x0-MSP)	$ 73,088,143	$ 2,270	**$ 63**
Expanded Model Savings	**$ 1,187,409**		

It is important that in the expanded model 35% of total volume would continue shipping to Minneapolis and 6% of volume is lost to bulk shipments. To calculate the total savings the expanded model adds to North Dakota shippers, the added value of the final sensitivity is multiplied by 59% of North Dakota's total supply. Logic states that to find the added value a Minot terminal would create for North Dakota, the added value is multiplied by total volume shipped through Minot.

Determining total savings is only the first step. It is important to consider how this surplus can be divided and how far the saving can be distributed. These implications are discussed in chapter six.

CHAPTER VI. SUMMARY AND CONCLUSIONS

Review of the Problem

North Dakota's transportation problem is centered on geography and volume. Being a land-locked state and not having an intermodal facility within the economic range of 150 miles from North Dakota production sites, transportation costs severely reduce shipper profit margins. North Dakota intermodal operators realize shipping containers to be inefficient and exhausting in today's transportation environment.

Options available to container shippers are limited and expensive. Two types of shippers are identified; hard and soft IP producers. Hard IP producers ship by container from origin to destination are forced to incur significant costs of draying containers roundtrip to the closest corresponding intermodal terminals of Winnipeg, Man.; Minneapolis, MN; Regina, Sask.; Chicago, IL, or directly to the point of export. Soft IP producers have an alternative option of shipping by bulk to the point of export and transloading goods in a container at the ocean port.

It is in the interest of North Dakota exporters to establish intermodal terminals within the state. Terminals exist in Dilworth, MN and Minot, ND. The Dilworth facility was once operational, but now stands open but idle as the BSNF no longer services this terminal due to its proximity to Minneapolis terminals. Minot also is idle but has the potential for being operational assuming it is able to ensure volumes and compete for the surplus of empty containers.

Due to the low profit margins realized by agricultural products, ocean carriers would rather return empty containers to Asian export markets without making stops.

Consumer goods exported from Asia having high profit margins create a large revenue stream to ocean carriers, giving them priority over goods exported from North Dakota.

The intermodal problem also lies within rail networks willingness to cooperate by repositioning equipment to regions of relatively low volume. Hindering rail cooperation is that a large investment has been made in the existing bulk rail system and investing in container traffic would detract from previous investments. This is further compounded in that North Dakota consists of less than 2% of the BNSF Railway revenue. Due in part to the narrow profit margins on agricultural commodities (North Dakota's greatest export) and volatile shipping needs throughout the year, the BNSF has found it to be cheaper to bypass North Dakota in route to the Pacific North West.

In recent years, the BNSF has been willing to explore the feasibility of stopping at an intermodal facility in Minot, North Dakota. However, because the BNSF must ensure that profits are not lost in doing so, they have required minimum volumes be shipped out of Minot with each stop. In other words, North Dakota producers need to consistently be meeting specific volume requirements set by the BNSF. Until they do so, the risks associated with shipping demand faced by the BNSF outweigh the benefits of stopping in North Dakota.

In essence, the problem is two-fold. A number of opinions exist as to which player among network operators is the bigger hindrance, the rail network or ocean carrier; both views are presented. One concludes that railroads are unwilling, or shipper value does not provide repositioning rates justifiable to bring empty equipment to North Dakota. On the other hand, ocean carriers may be unwilling to create a pool of containers in an area of relatively low volume making it nearly impossible for rail networks to reposition empties at a reasonable rate to North Dakota. Either way, the problem truly lies within North Dakota's limited volumes relative to the metropolitan areas of Minneapolis and Chicago.

Review of the Objective

The purpose of this research is to develop a model that evaluates tradeoffs regarding the development of intermodal shipping capabilities in North Dakota. A transportation strategy involving cooperation among key industry players is introduced as strategic behavior to accomplish the goals of establishing an intermodal terminal in North Dakota. The following are specific objectives to the research process:

6. Examine historical and current issues pertaining to intermodal transportation in North Dakota.
7. Develop an empirical model to evaluate intermodal pricing, revenues, and demand.
8. Conduct a sensitivity analysis on key random variables and interpret the results.
9. Analyze a variety of coalition cooperative efforts among key players and their effect on North Dakota's transportation environment.
10. Describe a business model that could enable efficient intermodal transportation for North Dakota intermodal operators.

The five objectives outlined in chapter one are achieved. Chapters one and two examined the historic and current issues pertaining to intermodal transportation both globally in and specific to North Dakota. Chapter three develops the theory and empirical model used by chapter four's model development.

The model built in chapter four is specific to the objective function goals, minimizing transportation costs for North Dakota exporters. Examining both the base case model and sensitivities applied to the base model allowed for examining today's transportation environment and its potential. The results are reported in chapter five and applied to game theory. Incorporating the results to game theory allows development of a business model focused on subsidizing network operators to cooperate and reposition containers to service North Dakota.

Review of the Procedure

A linear programming model was developed to analyze logistical costs and payoffs associated with varying game alternatives. Data collected was analyzed using GAMS software to determine the cost minimizing solutions for exporters across the eight regions from North Dakota. Forcing the model to always recognize an unmet demand ensured an analysis was provided from each origin. This is a key element to gaining a holistic perspective of North Dakota's transportation problem; the model proves shippers in Western North Dakota result to adopting a strategy different from shippers in the east.

The base case aimed to represent the current environment of transportation options available to North Dakota exporters. The base case assumed hard IP production for all shipments, forcing containers to be stuffed at their origin and drayed to an intermodal terminal. The base model did not include the Minot terminal as a potential shipping solution. Sensitivity tests were then applied to answer "what if" questions pertaining to North Dakota's transportation potential.

The first sensitivity included a bulk shipping option. Assuming the shipper is able to ship soft IP products by bulk and transloading goods from rail cars into a container at the port. This shipping method is currently used, but was eliminated from base model because many consumers, especially in the case of food products, require goods to travel by container from origin to destination (i.e. hard IP). The second sensitivity test removed the first, assuming all products are hard IP, and introduced Minot as an intermodal container terminal. The third sensitivity was applied to understand the differences between containerized shipping versus bulk. The model determined uniform results to sensitivity two.

The final sensitivity accounted for the weight differences experienced by the two transportation strategies; containers shipped from interior container terminals must be inflated to meet TEU demand. In other words, it takes a larger number of containers originating from interior terminals loaded at 21 metric tons per TEU to equal the shipping demand specified in 25 metric ton units. The completion of this third strategy yielded the expanded model examined.

The expanded model, including the above sensitivities, was studied in greater depth by applying sensitivity tests related to repositioning costs, container stuffing fees, Minot's handling fee, and volumes of North Dakota's supply. Repositioning of empty containers was examined by forcing all containers to be positioned from Chicago. This was achieved by eliminating from the model the option to reposition containers from Minneapolis. The second test, model sensitivity to the fees of stuffing containers at the ocean port, was analyzed by decreasing costs to examine shipping by bulk versus container. The third test looked specifically to Minot's terminal handling fees. Minot charges $100 per TEU in handling fees. To conduct this sensitivity, Minot's terminal handling fees were analyzed from a negative five hundred dollars to a positive five hundred. The logic for analyzing negative port handling follows the Brandenburger & Nalebuff (1996) idea of paying customers to play. One of Minot's biggest hindrances is the need for consistent volume; without it, Minot will fail.

Review of the Results

Base model results indicate hard IP producers in North Dakota realize minimized costs by draying containers to the intermodal terminals of Saskatoon, Winnipeg, or Minneapolis. Goods shipped to Saskatoon go to Prince Rupert by rail, goods shipped to Winnipeg travel by rail to Vancouver, and finally, goods out of Minneapolis are shipped to Seattle-Tacoma.

Reduced costs provided by model results are examined to determine which regions need to consider alternative shipping routes. Reduced costs illustrate the potential exceptions to shipping regions with more than one shipping option. When considering the reduced costs of x_1 (drayage from origin to intermodal terminal) it is important to note that regions ND1, ND5, ND6, ND7, and ND8 are not considered for alternative shipping routes. This was determined by looking to the reduced costs of the closest shipping alternative. However, given reduced costs less than $150 per TEU for alternative routes in regions ND2, ND3, and ND4, reduced costs are examined.

Reduced costs suggest that region ND2 and ND4 consider shipping to Winnipeg a cost minimizing solution. However, reduced costs for region ND3 prove the opposite suggesting Minneapolis to be considered as a shipping alternative to Winnipeg. The reduced costs for x_2 movements in the base case are as following. For all x_2 movements originating in Minneapolis, the cost minimizing solution provides that rail shipments travel to Seattle-Tacoma. The next closest alternative is to ship from Minneapolis to Portland, OR. The reduced costs associated with shipping to Portland rather than Seattle-Tacoma is approximately $350. This large reduced cost provides that the x_2 movement chosen by model is a true optimum.

Lastly, as seen by Figure 5.1, all shipments travelling across the x_3 movement travel to Japan. Because the model has no restrictions on the number of TEUs needed at each destination, and given that demand for each destination is greater than total North Dakota supply, the model always chooses the shortest distance route. Thus, the model always chooses shipping to Japan over other destinations due to Japan's proximity to North America's west coast.

It is important that other shipping destinations are not far behind. For ocean shipments leaving Seattle-Tacoma, four other destinations have reduced costs within forty dollars of shipping to Japan. In practice, producers first consider market demand and then begin developing a shipping strategy.

Sensitivities were applied to answer "what if" questions related to North Dakota transportation. The first sensitivity test allows for cost of shipping by bulk to the point of export versus required loading of containers at the site of production. Results show that for the three regions encompassing the eastern border and southeast corner of North Dakota (ND4, ND7 and ND8), stuffing containers at the site of production remain the cost minimizing solution. For all other regions, the model displays a bulk shipment option to realize minimized costs.

Sensitivity two has hard IP shipments and includes the Minot intermodal terminal. Results show that North Dakota realizes the Minot terminal as an important shipping option. Seven of the eight producing regions send at least a portion if not all goods through Minot. With the exception of goods in region ND8, Minot is the cost minimizing strategy the majority of North Dakota's volume. Region ND8 ships to Minneapolis as the cost-minimizing route for total volume. These results were the same as those of sensitivity three applying both the bulk shipment option and including Minot.

The expanded model and final sensitivity accounts for the limitation placed on a containers load weight moving by rail is 21 metric tons per TEU. The addition of this parameter slightly changed model results from models two and three. Once the weight difference for shipping by bulk versus container had been accounted, region ND4 realized a bulk shipment option to provide the cost minimizing solution for 28% of regional volume. Being ND4 is the only region utilizing the bulk shipment option, all other regions followed previous shipping patterns with the exception of ND7 now shipping total volume through the Minot terminal. ND8 continued utilizing Minneapolis for total production volume.

Sensitivities were then conducted on the expanded model. These sensitivities display a shift in shipping patterns due to the cost of repositioning empty containers, container stuffing fee's, and Minot's terminal handling fee.

The cost of repositioning empty containers from Chicago rather than Minneapolis was examined. Derived from STB Waybill data, it is determined that the cost of repositioning a container from Chicago to Minot is increased by $82 per TEU from the cost of repositioning empty containers from Minneapolis. Results indicate that 57% of North Dakota exporters will continue shipping by container from origin to destination regardless of increased costs accrued by repositioning empty containers from Chicago. This estimation is reduced from the 93% choosing to ship by container when empty containers are repositioned from Minneapolis. It is concluded that 43% of North Dakota total volume is highly sensitive to the costs of repositioning empty containers.

Under the assumption that containers must be repositioned from Chicago, the model also concludes that region ND4 will continue shipping 28% of regional volume by bulk in addition to ND8 shipping total volume by bulk rather than container. However, model reduced costs provide that if shipping by container to Minneapolis were to be reduced by $30, it would once again be considered the cost minimizing solution. Provided such a small reduced cost, results are not significantly different from those having repositioned empty containers from Minneapolis.

Sensitivity two displays the expanded models sensitivity to container stuffing fees. For the case of repositioning containers from Minneapolis, if the transloading fees were to drop to $100 per TEU from $400 per TEU, five of North Dakota's eight shipping regions would realize bulk shipping to generate the cost minimizing solution. This sensitivity analysis displays a sharp decline in number of regions shipping by bulk after increasing this rate from $100. The expanded model assumes a transloading fee of $400 per TEU and results in approximately 6% of total volume realizing bulk shipping as the cost minimizing solution.

This estimation is increased to 42% assuming shippers overall costs are increased by reposition containers from Chicago rather than Minneapolis. The results considering increased costs accrued from repositioning containers from Chicago created a more consistent decreasing trend than the sharp declines seen by the case of repositioning containers from Minneapolis.

The third sensitivity determined how model demand for shipping via Minot reacts to an increase or decrease in Minot's base handling fee of $100 per TEU. Minot's synthetic demand curve displays a consistent demand between $100 and positive $200 per TEU handling fee. The base model currently assumes a handling fee for Minot of $100 per TEU. However, model results conclude that Minot could increase handling fees by $100 and maintain consumer demand.

Implications

Model results prove the importance of having an intermodal terminal within North Dakota. The research developed generates an added value of individual sensitivities included to the base model. The model savings encourage cooperation among North Dakota players to incentivize network operators to service the state. Thus, rather than passing blame, the better approach is to ask, what will it take to bring in ocean carriers business?

The estimated surplus of the expanded model assuming weight restrictions has a savings of less than $1.5 million. This estimation seems large, but the money is not nearly enough to satisfy network operator bottom lines. When the weight restriction is eliminated, model savings are increased to $9 million. The BNSF is working to eliminate weight restrictions, but until this goal is achieved, it is difficult for Minot to gain a savings large enough to incentivize ocean carriers and railroads to reposition equipment to North Dakota.

Limitations of the Study

This study was based on supply volumes from a survey conducted nearly a decade ago. Having updated information pertaining to North Dakota's annual volume of containers leaving the state would provide more accurate results. For this reason volume should have been considered as a random variable to determine objective function values at a range of volumes. This is a significant barrier to the research. From discussing model results with industry professionals, it is estimated that container volumes have increased by at least

10,000 containers per year due to increased trade of DDG's; a topic outlined in chapter two as potential growth for North Dakota supply. Accounting for the additional 10,000 containers would have increased Minot's added value and implications greatly more encouraging for Minot.

Randomness should also be applied to the availability of empty containers and costs examined in times of both surplus and shortage; this would involve more data than what is currently available. Applying random variables is necessary to capturing North Dakota's dynamic transportation problem, changing by exogenous factors. As the economy fluctuates so will dynamics of containerized shipping; as seen in 2009 with the large number of ocean vessels idle due to the economic downturn.

Other exogenous factors not captured are non-quantifiable issues such as political relationships that add dynamics to the issue.

Need for Further Study

North Dakota has been pushing toward the scenario of repositioning ¾ of a weekly unit train to Dilworth, MN and the other ¼ repositioned to Minot. The feasibility of this strategy should be considered using similar linear programming techniques. Additional costs are employed by stopping the train twice for repositioning. It is suspected that the added value will decrease due to the assumed increased cost.

Lastly, a forecast should be made of current and potential DDG demand. This information should be applied to the model as potential supply for North Dakota container volume. The estimated 10,000 currently exported containers of DDGs from North Dakota ethanol plants should be added to their corresponding regional volumes and the model re-estimated. Because two of the three ethanol plants being located in Richardton North

Dakota and Casselton North Dakota, would likely utilize the Minot terminal; it is important to analyze this increased volume; Hankinson most likely shipping to Minneapolis would have no effect on Minot's potential for success.

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