Feasibility of Containerized Transport in Rural Areas and its Effect on Roadways and Environment: A Case Study

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AFCERC Commodity Market Research Report No. CP-01-11
March 2011

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FEASIBILITY OF CONTAINERIZED TRANSPORT IN RURAL AREAS AND ITS EFFECT ON ROADWAYS AND ENVIRONMENT: A CASE STUDY

Agribusiness, Food, and Consumer Economics Research Center (AFCERC) Commodity Market Research Report No. CP-03-11, March 2011 by Dr. Francisco Fraire, Dr. Stephen Fuller, Dr. John Robinson and Dr. Sharada Vadali.

ABSTRACT

Congested roadways in Texas' metropolitan centers are important arteries for transporting agricultural products into domestic and international markets. It follows that truck-transport of these commodities contributes to the observed congestion and delay in these urban centers. As an example, cotton, which is a major field crop in Texas, is transported via Dallas-Ft. Worth and Houston roadways to access container transport to the international market, the principal outlet for this commodity. This study examines the feasibility of investment in a west Texas intermodal terminal that focuses on cotton exports as well as its implications for reducing roadway maintenance costs, CO_2 emission and truck-transport in Texas' metropolitan areas. The analyses show an intermodal terminal in west Texas' intensive cotton production region (Lubbock, Texas) would be economically viable, reducing roadway maintenance costs, CO_2 emission, and truck-travel in the Dallas-Ft. Worth metropolitan center.

ACKNOWLEDGEMENTS

Support for this research was provided in part by a grant from the U.S. Department of Transportation, University Transportation Centers Program to the University Transportation Center for Mobility™ (DTRT06-G-0044). Special appreciation is expressed to the University Transportation Center for Mobility™ for funding this effort (UTCM 07-07). Sincere appreciation is also expressed to the Texas State Support Committee (Cotton Incorporated), Cotton Incorporated Core Funding, Texas Department of Agriculture (Food and Fiber Research Program), National Cotton Council (Wilbur Smith Associates), and the USDA-Agricultural Marketing Service's Transportation and Marketing Program for funding various aspects of this research effort. Without funding from these agencies, this study could not have been successfully completed. Equally important are several individuals who made selfless contributions. These include Dr. Denver Tolliver, Upper Great Plains Transportation Institute at North Dakota State University, who offered valuable counsel regarding marginal roadway pavement costs and students that often toiled at tedious research activities. The students include: Maria Afonso, Atul Chavan, Pei-Chun Lai, Li Lin and Scott Tiemann.

Key words: Intermodal terminals, cotton transportation, spatial model

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FEASIBILITY OF CONTAINERIZED TRANSPORT IN RURAL AREAS AND ITS EFFECT ON ROADWAYS AND ENVIRONMENT: A CASE STUDY

EXECUTIVE SUMMARY

Texas, a state whose economy is closely tied to the agricultural, manufacturing and mining (petroleum) sectors, experiences high levels of congestion in several of its leading economic centers. Dallas-Ft. Worth and Houston-Baytown rank as the fifth and sixth most congested areas in the United States with roadway travel times increasing 13 percent during peak congestion periods. Unfortunately, the congested roadways in Dallas-Ft. Worth and Houston are important arteries for transporting agricultural products and commodities into domestic and international markets. For example, cotton, which is a major field crop in Texas, is transported over the roadways of these urban centers for purposes of accessing container transport to the international market, the principal outlet for this commodity.

This study examines the economic feasibility of investment in an intermodal terminal in west Texas and its implications for reducing roadway maintenance costs, CO_2 emission and truck-transport in Texas' metropolitan areas. The study focuses on cotton, a leading agricultural commodity in Texas, which is highly dependent on the international market and truck transport into the Dallas-Ft. Worth complex for purposes of accessing containerized railroad transportation to West Coast ports. An intermodal terminal in west Texas would allow cotton to access the intermodal system near its production location, removing the need for truck transport into the Dallas-Ft. Worth metropolitan area. Because the assembly of cotton into the Dallas-Ft. Worth railroad hubs is at distances up to 335 miles, truck-miles and roadway maintenance may be significantly decreased as would CO_2 emissions with the introduction of rural intermodal terminals.

Many of the analyses were accomplished with a spatial model of the U.S. cotton industry.
The developed model features details regarding cotton handling, storage and transportation activities. The cost-minimizing, transshipment model includes gins, warehouses, domestic textile mill regions, inland intermodal terminals, and U.S. ports and border-crossing locations. The transshipment model features 811 gins, 415 warehouses, 13 port areas, four border-crossing locations, four inland intermodal terminals that are central to the cotton trade, 37 transloading warehouses at inland intermodal terminal locations, eleven domestic textile mill demand regions, and the model represents a cotton crop year (four quarters). Domestic demands are based on historical mill consumption in southeast U.S. regions and foreign demands are fixed at historical cotton export levels at U.S. ports and border-crossing locations.

The cotton transportation and logistics network featured in the national spatial model links the cotton gin plants to cotton warehouses, and links warehouses to domestic mill demand regions, inland intermodal terminals, ports, border-crossing locations, and other warehouses (transloading warehouses) by quarterly transport rates. Further, the inland intermodal terminals are connected to selected ports in the national model. Truck transportation is central to movement of U.S.

baled cotton. Cotton gin plants ship entirely by truck to warehouses, and warehouses ship large quantities by truck to domestic mill demand regions, ports, transloading warehouses, border-crossing locations, and inland intermodal terminals. Railroads transport large quantities of cotton in containers from selected inland intermodal terminal locations to port areas and selected warehouses ship via boxcars to ports, domestic mill sites, and border-crossing locations.

The analyses show an intermodal terminal in west Texas' intensive cotton production region (Lubbock, Texas) to be economically viable. It is estimated that the facility could attract up to 2 million bales or nearly 30% of Texas' average cotton production. For example, an intermodal terminal capable of handling 18,000 containers per year (1.58 million bales) would require an investment of $10.69 million and could be expected to earn a rate of return on investment exceeding 20 percent. Additional analyses show the 18,000 container-per-year terminal would attract profitable volumes during the region's lowest cotton production years, but would be vulnerable if an existing intermodal terminal at a nearby location (Amarillo, Texas) were to commence cotton shipments to West Coast ports.

Implementation of an intermodal terminal in west Texas that handles approximately 2 million cotton bales is estimated to annually reduce truck (80,000 pound, 5-axle) travel on state roadways by 3.75 to 4.53 million loaded truck-miles and lower pavement expenditure by approximately $1 million. This positive externality suggest an opportunity for public and private sector cooperation. Further, the reduced truck-miles expended to assemble Texas cotton to intermodal facilities is estimated to reduce CO_2 emissions by 42 to 47 percent (14,978 to 18,079 tons) relative to the current transportation system. The estimated value of reduced CO_2 emission ranges up to $.705 million per year. Finally, estimated traffic into the Dallas-Ft. Worth metroplex would be reduced by 13,800 to 16,700 trucks per year with introduction of the west Texas intermodal terminal.

In summary, the analyses suggest that investments in intermodal terminals in rural areas may offer opportunities to improve marketing system efficiency, and reduce roadway maintenance cost and vehicle emission.

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INTRODUCTION

Agriculture, manufacturing, mining and related sectors in the United States are highly dependent on an efficient freight transport system, connecting its businesses to domestic and world markets. Globalization mandates the availability of reliable and efficient freight transportation to enhance international competitiveness as well as economic growth in the domestic economy. As the economy has grown and freight volume increased, the capacity of existing infrastructure has become strained which has diminished the reliability and efficiency of U.S. freight transportation.

Texas experiences high levels of congestion in several of its leading economic centers. INRIX (2009) reports Dallas-Ft. Worth and Houston-Baytown rank as the fifth and sixth most congested areas in the United States with roadway travel times increasing 13 percent during peak congestion periods. Similarly, the Texas Department of Transportation (2008) reports that eight of the state's ten most congested roadway segments are in these economic centers with the annual cost of delay per roadway segment ranging from \$50 to \$88 million. Unfortunately, the congested roadways in Dallas-Ft. Worth and Houston are important arteries for transporting agricultural products and commodities into domestic and international markets. For example, cotton, which is a major field crop in Texas and whose principal outlet is the international market, is transported over the roadways of these urban centers for purposes of accessing container transportation.

The Transportation Research Board (TRB 2007), in the recent publication titled *Rail Freight Solutions to Roadway Congestion—Final Report and Guidebook*, note the potential to reduce congestion on roadways by transferring traffic to railroads, and importantly note the associated decrease in deterioration of existing roadways and the decrease in pollution that results from this transfer of traffic as well as the improvement in roadway safety. In addition, the TRB report notes the potential for private-public cooperation which could include cost-sharing of construction and the operation of future intermodal terminals.

This study examines the feasibility of investment in an intermodal terminal in west Texas and its implications for reducing roadway maintenance costs, CO_2 emission and truck traffic in Texas' metropolitan areas. The study focuses on cotton, a leading agricultural commodity in Texas, which is highly dependent on the international market and on truck transport into the Dallas-Ft. Worth complex to access containerized railroad transportation to West Coast ports. Conceptually, an intermodal terminal in west Texas would allow cotton to access the intermodal system near its production location, removing the need for truck transport into the Dallas-Ft. Worth metropolitan area. Because the assembly of cotton into the Dallas-Ft. Worth railroad hubs is at distances of up to 335 miles, truck-miles and roadway maintenance along with CO_2 emissions may be significantly decreased by the introduction of a rural intermodal terminal.

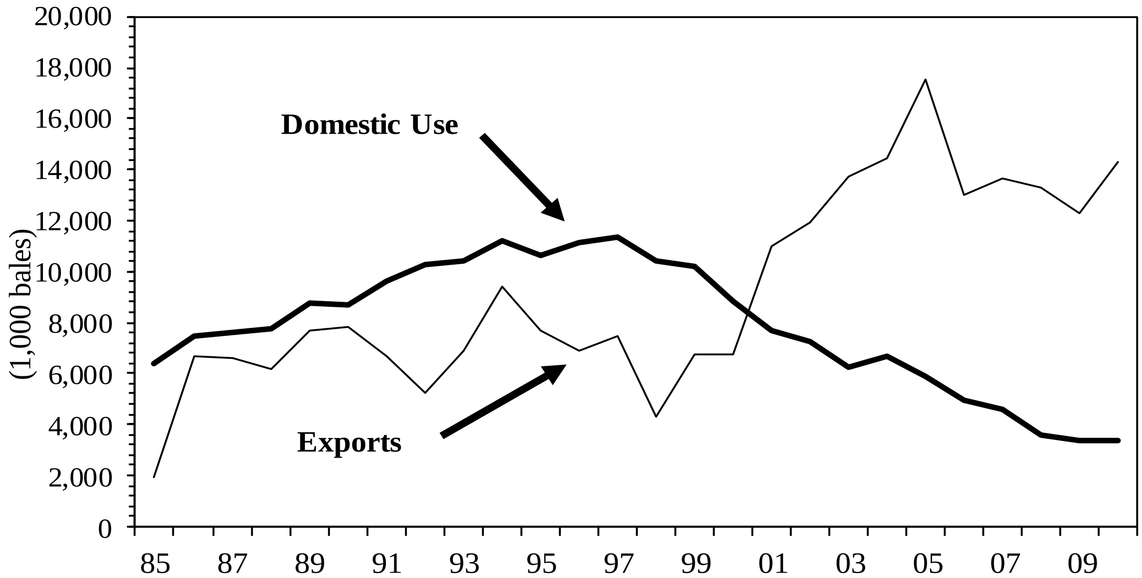
The objectives of this study are to (1) determine the economic feasibility of an intermodal terminal in the intensive cotton production region of west Texas and evaluate the sensitivity of the intermodal terminal's feasibility to selected exogenous forces, (2) estimate truck traffic diversion from the Dallas-Ft. Worth metropolitan area and reduced roadway maintenance expenditure resulting from this terminal , (3) estimate reduction in CO_2 emission associated with the intermodal terminal and the value of the reduced emission and (4) evaluate the opportunity for private-public cooperation regarding intermodal terminals in rural Texas. The study does not measure any possible benefits from the west Texas terminal that relate to reduced traffic congestion, crashes and noise or possible gains to other businesses that are using these roadways. It is assumed that the diversion of cotton truck traffic, while substantial regarding cotton transportation and logistics, is not large as compared to total traffic on the highway network linking west Texas into the Dallas-Ft. Worth metropolitan area.

Many of the analyses were accomplished with a spatial model of the U.S. cotton industry that features cotton handling, storage and transport activities that link cotton gins to warehouses and ultimately to intermodal terminals, domestic textile mills and U.S. port areas. The developed spatial model features considerable detail regarding cotton transportation and logistics. Domestic cotton demand is represented in regions that feature textile mills and foreign demand is represented at U.S. cotton ports.

BACKGROUND

The transport and logistics system serving the U.S. cotton industry has undergone important changes as a result of the demise of the domestic textile industry and the corresponding growth in cotton exports. Currently, exports comprise nearly 80 percent of annual cotton disappearance (Figure 1). Cotton that had historically been transported by truck and railcar to southeast U.S. textile mills is now largely routed to export via the U.S.'s West Coast, Gulf of Mexico and southeast ports, and the Mexican border. Survey data show Texas, the leading cotton producing state, ships the majority of its export-destined cotton to West Coast ports (Long Beach/Los Angeles). Nationally, about 48 percent of U.S. cotton is exported via West Coast ports, with Gulf of Mexico and East Coast ports handling about 17 and 16 percent, respectively, and border-crossing locations accommodating about 19 percent of exports. All cotton exported from U.S. ports moves in marine containers and because of unequal trade flows between Asia and the U.S., considerable U.S. cotton is backhauled in containers to Asian textile mills. Unfortunately, many of the intense cotton producing regions in Texas and the U.S. are geographically remote and cannot efficiently access the westward flow of empty containers to West Coast ports.

Figure 1: Domestic U.S. Cotton Use and U.S. Exports 1985/86 – 2010/11



Source: USDA, Office of the Chief Economist, 2010

REVIEW OF LITERATURE

A review of literature indicated modest effort to construct spatial models of the U.S. cotton industry that incorporated transportation and logistics detail; however, there has been research that focused on the spatial dimension of the cotton ginning industry giving consideration to optimal number, size and location of these facilities (Fuller, Randolph, and Klingman 1976). Although the spatial dimension has not been the focus of cotton marketing research, similar agricultural commodities have been successfully modeled in a spatial equilibrium framework. For example, spatial equilibrium models (quadratic programming) of the international grain economy have recently been employed by Fellin, Fuller, Kruse, Meyers and Womack (2008) to evaluate a catastrophic event on the U.S. inland waterways, and Wilson, Dahl, Taylor, and Koo (2007) have developed for the U.S. Army Corps of Engineers a cost-minimizing spatial model of the world grain economy for purposes of estimating long-run grain movements on the Mississippi River.

The Upper Great Plains Transportation Institute (2007) examined the feasibility of a logistics center featuring container/trailer intermodal transportation in rural Minnesota and North Dakota. The study surveyed shippers/receivers in the area to gain information on potential users of the facility, carried out an economic-engineering study to gain insight on fixed and variable costs per lift under varying volume levels, and examined potential funding sources for investment in the intermodal facility. In addition, Vachal and Berwick (2008) examined the feasibility of using a container-on-barge facility to export Illinois grain to Asia and by pass congested roadways in the

Chicago area. The low-cost option involved shipping containers of grain to Gulf ports via the Mississippi River. The Minnesota Department of Agriculture in collaboration with Wilbur Smith Associates (2008) examined the feasibility of investments in intermodal terminals on short-line and regional railroads in the Midwest. The analyses show containerized grain movement by short-line railroads to be economically feasible under limited conditions.

Washington State Department of Transportation (2003) in a study titled *East Washington Grain-Hauling Short-Line Railroads* examined the implications for pavement deterioration and road maintenance costs resulting from abandonment of the Palouse River and Coulee City Railroad in eastern Washington State. It was estimated that 645 miles of roadway would be affected by the rail abandonment. The additional expenditure on road maintenance resulting from abandonment was estimated to be near $39 million. Related studies by Babcock, Bunch, Sanderson, and Witt (2003a, 2003b) estimated road damage costs resulting from the proposed abandonment of short-line railroads serving Kansas. As part of the research effort, a four-step pavement damage model by Tolliver and HDR Engineering (2000) was employed to calculate additional damage costs for county and state roadways, and a time decay model with an equivalent single-axle model was employed to evaluate the pavement service life. The study found short-line railroads in the Kansas study region annually saved $57.8 million in roadway damage costs.

Warner and Terra (2006) estimated the reduction in pavement damage to Texas roadways that results from the operation of the state's short-line railroads. To accomplish study objectives, it was necessary to estimate additional pavement damage associated with increased truck traffic resulting from short-line abandonment. The estimated pavement damage was calculated using a method outlined by Bitzan and Tolliver (2001). They estimated pavement damage to rural interstate highways was 12.7 cents per truck-mile while the pavement damage to rural major collectors was estimated at 30.5 cents per truck-mile. After considering federal and state fuel taxes paid by trucks, the uncompensated road damage was estimated to be 5.03 cents per truck-mile for rural interstate highways and 22.83 cents per truck-mile on rural major collectors. Additional insight into highway-related costs by various user types is presented in *Federal Highway Cost Allocation Study: Summary Report* by the U.S. Department of Transportation (USDOT 1997).

Because of the diversity of opinion among states, carriers, shippers and interest groups regarding appropriate truck size and weight regulations, the U.S. Department of Transportation (USDOT) carried out a study to address a variety of related issues: the resulting study document was titled *Comprehensive Truck Size and Weight Study* (USDOT 2000a). The study estimates expected vehicle-miles traveled under alternative truck size and weight regulations and estimates the effect on a variety of costs including pavement, bridge, congestion, energy and shipper costs. Chapter 6 of the *Comprehensive Truck Size and Weight Study* (USDOT 2000b) report offers details on the effect of truck weight, axle configuration, tire characteristics and related factors on pavement cost.

Andrieu and Weiss (2008) examined the tradeoff between carbon footprint, transport costs, time, and risk in alternate supply chains. The study reviews methods and tools available for the measurement of CO_2 for major transport modes under alternative operating conditions. They note the difference in CO_2 emission estimates per tonne-kilometer proposed by often-used methods, giving particular attention to the *Greenhouse Gas Protocol Initiative* (World Resource Institute 2003) and the EPA SmartWay Transport (2006) tool. In addition, Andrieu, et al. (2008), following the approach by McKinnon (2007), adjusts the calculated emission parameters to reflect the truck's capacity utilization (backhaul frequency). The Environmental Protection Agency's Office of Transportation and Air Quality (EPA 2010) recently developed a modeling system to estimate emissions for mobile sources that covers a broad range of pollutants. The developed model (Motor Vehicle Emissions Simulator referred to as MOVES) estimates emissions from cars, trucks and motorcycles. It shows the atmospheric emission rate for class 8 trucks (heavy duty trucks) averages about 2000 grams of CO_2 per mile at average speeds of 50 to 60 miles per hour. The analysis also shows emissions are affected by truck capacity utilization (backhaul frequency) through its impact on fuel use.

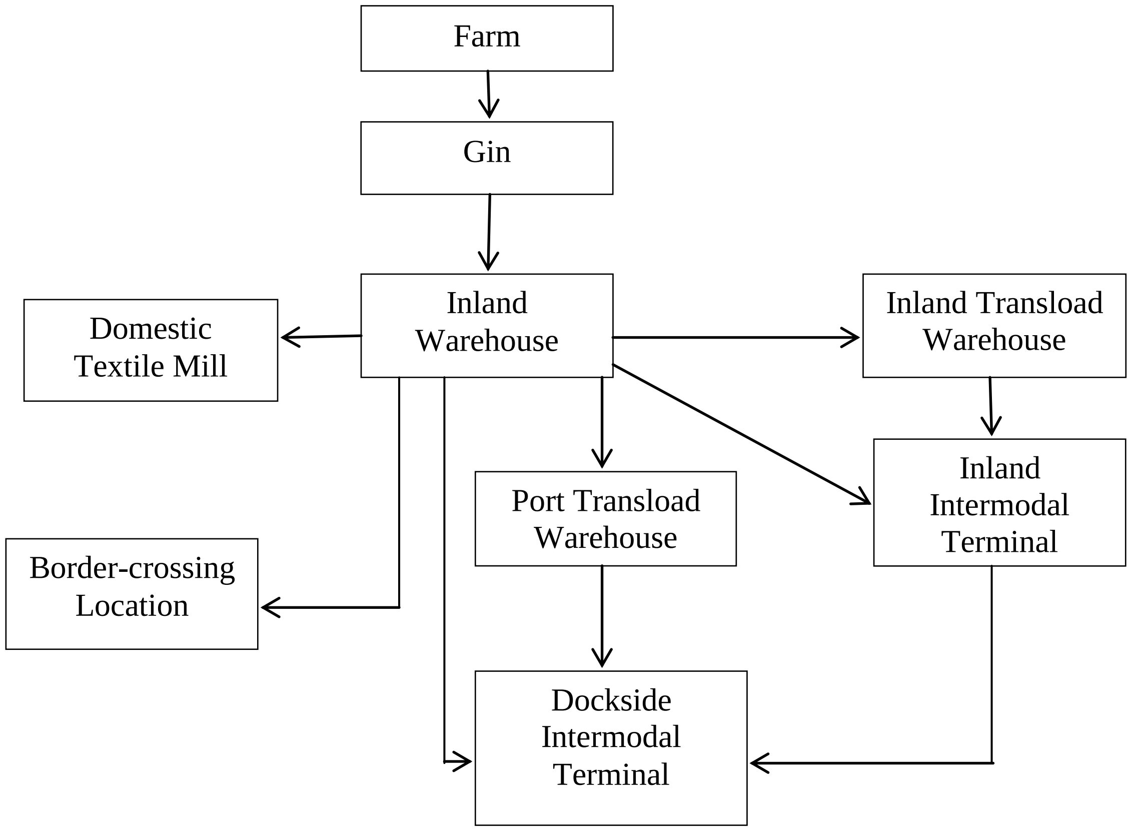
Franzese, Knee and Slezak (2009) estimate the effect of load size (frequency of empty haul) and truck-tire configuration on fuel efficiency of class 8 trucks. Their analyses suggest the reasonableness of the rule of thumb "each additional 10,000 pounds of payload decreases fuel economy about 5 percent." The Federal Railroad Administration (USDOT 2009) provides a comparative evaluation of rail and truck fuel efficiency on corridors where both compete. The study compares fuel efficiency for 23 moves. Eleven of the moves compared fuel efficiency of trucks with double-stack container cars for moves ranging from 294 to 2,232 miles with results indicating rail transport was 2.2 to 5.5 times more fuel efficient than truck. Additional insight on truck fuel efficiency was offered by a recent publication (TRB 2010), *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.*

The Transportation Research Board (TRB 2009) report titled *Public and Private Sector Interdependence in Freight Transportation Markets* examines the relationship between public and private sector stakeholders in the freight transportation industry and shed light on the perspective of each with the intent to improve communications and freight policy planning. The report notes the criteria to evaluate investment decisions by the private and public sector is often different and these differences are often unrecognized by the other sector. Examples where the public and private sectors have successfully cooperated are offered citing the Alameda Corridor project, the Northeast Ohio Intermodal Terminal initiative and others.

SPATIAL COTTON MODEL

The spatial model developed for this study features details regarding cotton handling, storage and transportation activities. The cost-minimizing, transshipment model includes gins, warehouses, domestic textile mill regions, intermodal terminals, and U.S. ports and border-crossing locations. The transshipment model features 811 gins, 415 warehouses, 13 port areas, four border-crossing locations, four inland intermodal terminals that are central to the cotton trade, 37 transloading warehouses at inland intermodal terminal locations, 11 domestic textile mill demand regions, and the developed model represents a cotton crop year (four quarters) that extends from August 1 through July 31. Domestic demands are based on historical mill consumption in southeast U.S. regions and foreign demands are fixed at historical cotton export levels at U.S. ports and border-crossing locations (Figure 2).

Figure 2: Cotton Supply Chain Represented in Spatial Model



Cotton supply is generated in the first quarter of the crop year and carried forward into subsequent quarters. Cotton supply includes carry-in stocks plus cotton production. Cotton handling and storage costs are incurred at warehouses, intermodal facilities, ports and border-crossing locations. Truck transportation typically dominates except for those transportation links between intermodal facilities and ports that involve containerized rail movements, and selected routes between warehouses and ports and border-crossing locations where rail transport (boxcar) has some role.

A cost-minimizing, transshipment model was developed to represent the national cotton marketing system with its associated handling, storage and transportation network. A description of the mathematical model follows:

(1) Objective function:

$$Min \sum_i \sum_w \sum_t c_{iw} X_{iwt} + \sum_w \sum_n \sum_s \sum_t c_{wnst} X_{wnst} + \sum_w \sum_l \sum_t c_{wlt} X_{wlt} + \sum_w \sum_k \sum_s \sum_t c_{wkst} X_{wkst} + \sum_j \sum_m \sum_s \sum_t c_{jmst} X_{jmst} + \sum_k \sum_n \sum_t c_{kn} X_{knt} + \sum_w \sum_t cs_w H_{wt}$$

(2) Quarterly Demand Constraints:

2a.

$$\sum_w \sum_s X_{wnst} + \sum_k X_{knt} \geq D_{nt}, \quad for\ all\ n, t.$$

2b.

$$\sum_w X_{wlt} \geq D_{lt}, \quad for\ all\ l, t.$$

2c.

$$[(\sum_{it} S_{it} + \sum_w H_{w0}) - (\sum_n \sum_t D_{nt} + \sum_l \sum_t D_{lt})] \cdot \gamma_u \leq \sum_{v \in u} \sum_j \delta_v H_{j4}, \ for\ all\ u.$$

(3) Quarterly Supply Constraints:

$$\sum_w X_{iwt} \leq S_{it}, \ for\ all\ i, t.$$

(4) Warehouse Shipment Balance Constraint:

$$\sum_n \sum_s X_{jnst} + \sum_l X_{jlt} + \sum_k \sum_s X_{jkst} + \sum_m \sum_s X_{jmst} + H_{jt} - H_{j,t-1} \leq \sum_i X_{ijt}, \quad for\ all\ t\ and\ j \subset w.$$

(5) Transloading Warehouse Balance Constraint:

$$\sum_n \sum_s X_{mnst} + \sum_l X_{mlt} + \sum_k \sum_s X_{mkst} + H_{mt} - H_{m,t-1} - \sum_j \sum_s X_{jmst} \leq \sum_i X_{imt}, \quad for\ all\ t\ and\ m \subset w.$$

(6) Quarterly Intermodal Terminal Shipment Balance Constraints:

$$\sum_n X_{knt} \leq \sum_w \sum_s X_{wkst}, \quad for\ all\ k, t.$$

(7) Quarterly Warehouse Storage Capacity Constraints:

$$H_{wt} \leq Capacity_{wt}, \ for\ all\ w, t.$$

(8) Non-negativity Constraint:

$$X_{iwt}, X_{wnst}, X_{wlt}, X_{wkst}, X_{jmst}, X_{knt}, H_{w,t} \geq 0, \quad for\ all\ i, j, k, l, m, n, s, t.$$

Equation (1) minimizes the costs associated (*C*) with handling, storage (*H*) and transportation (*X*) of baled cotton that originates at U.S. gins over the four quarters of a crop year that extend from August 1 through July 31. The letter *t* identifies the quarter, where *t* = Q1 corresponds to the initial quarter of crop year when harvest commences. The model allows cotton to be routed from gins (*i*=811) to warehouses (*w*=415) and then, for export-destined cotton, to transloading facilities (*m*=37), and inland intermodal terminals (*k*=4), before arriving at ports and border-crossings (*n* =17). Further, the model allows for direct shipment from warehouses to domestic mill demand regions (*l*=11), and ports and border-crossings (*n*=17). The cotton can be transported via five transportation systems (*s*=5). Lastly, quarterly storage in originating warehouses and transloading warehouses is allowed in all four quarters.

Equation 2a is a demand constraint requiring the shipment of predetermined quantities per quarter to ports and border-crossings (n) while Equation 2b is a constraint requiring predetermined quantities per quarter to domestic mill demand regions (l=11). The third demand equation (2c) specifies the ending stocks ($H_{j,4}$) in four regions (u). These regions are the mid-south, southeast, southwest, and west. Each region contains several states *(v)*. Therefore, given that $\delta_v = 1$ when state s belongs to region u, and zero otherwise, the equation distributes the excess supply into the model according to the proportions specified by γ_u, while allowing each warehouse's storage of cotton to be determined endogenously.

Equation (3) describes gin plants maximum output of baled cotton.

There are two types of warehouses ($w = j + m$) whose distinction is their ability to receive (m) or not receive (j) baled cotton shipments from other warehouses. Originating warehouses are generally located in proximity of cotton production and receive cotton from area gins. Transloading warehouses receive from other warehouses and gins and are typically in proximity of inland intermodal terminals and port areas. Equation (4) constrains the sum of quarterly shipments from originating warehouses to intermodal terminals (k), transloading terminals (m), ports (n) and mills (l), and storage for the next period (H_t) to be no more than incoming new crop quarterly supplies (X_{ijt}) plus carry-in storage stock (H_{t-1}) where $H_{j,0}$ refers to the stocks carried in from the previous year.

Equations (5) and (6) are similarly interpreted for the transloading warehouses and intermodal terminals, respectively. Notice that the transloading warehouses are a subset of the regular warehouses ($m \subset w$) . Thus, Equation (5) applies only to the transloading warehouses and is in place of Equation (4).

Equation (7) constrains the quarterly storage in warehouses to not exceed their capacity. Equation (8) is the standard non-negativity constraint in linear programming.

The specified model includes 811 gins and 415 originating warehouses located in seventeen states (Alabama, Arizona, Arkansas, California, Florida, Georgia, Kansas, Louisiana, Mississippi, Missouri, New Mexico, North Carolina, Oklahoma, South Carolina, Tennessee, Texas and Virginia). Four major intermodal terminals are featured at inland locations which include Memphis, Dallas, Houston and Lubbock. The Lubbock operation is currently privately operated, comparatively small, and available to few cotton shippers. The feasibility analysis focuses on the development of an intermodal terminal in Lubbock that is capable of accommodating all area shippers seeking its service. Thirty-seven transloading warehouses operate in these inland intermodal terminal centers and receive truck-delivered cotton from originating warehouses and gins. In addition, intermodal terminals operate in conjunction with selected port areas and receive containers of rail-transported cotton from inland intermodal terminals. In the model, the port intermodal terminals that receive rail-transported cotton are at the following locations: California (Los Angeles/Long Beach, San Francisco), Georgia (Savannah), Louisiana (New Orleans), South Carolina (Charleston), Texas (Galveston/Houston), Washington (Seattle) and Virginia (Norfolk). Additional ports included in the model are located in Mobile, Alabama; Everglades and Jacksonville, Florida; Gulfport, Mississippi; and Freeport, Texas. All ports in the model feature a transloading warehouse that receives truck-transported (flatbed/van) cotton which is placed in containers and drayed to dockside for export, and, in addition, all ports may receive source-loaded cotton (containers) that is truck-transported from originating warehouses. Border-crossing locations are featured in Detroit, Michigan; Buffalo, New York; and Laredo and Harlingen, Texas. Eleven domestic mill demand regions are included in the following states: Alabama (2), Georgia (2), North Carolina (2), South Carolina (2), Tennessee (1), Texas (1) and Virginia (1).

Because truck transport is central to the marketing of U.S. cotton, several truck assembly systems are featured in the model. In the model, trucks (flatbeds/vans) assemble baled cotton from gins to originating or transloading warehouses. Trucks are also central to the shipment of cotton from originating warehouses. Trucks (flatbeds/vans) may ship from originating warehouses to domestic mill demand locations, border-crossing sites, and transloading warehouses at inland intermodal terminal locations and ports areas. The transloading warehouses receive truckloads of cotton which are placed into containers and drayed to inland intermodal terminals or dockside depending on the location of the intermodal terminal. The containerized cotton received at inland intermodal terminals is loaded onto double-stack cars which are subsequently rail-transported to a port area for export. Containerized cotton exiting a transloading warehouse in a port area is drayed to dockside where it will be loaded onto a container ship for export.

One of the modeled truck assembly systems involves a truck, chassis and container (source-loaded) which travels to an originating cotton warehouse where the container is loaded and then transported to an inland intermodal terminal for loading aboard a double-stack container car for shipment to a port area. Similarly, truck, chassis and container (source-loaded) may transport cotton from originating cotton warehouses to ship dockside. The assembly system involving truck, chassis, and container (source-loaded) removes the need to transship cotton through transloading warehouses which reduces handling and associated drayage charges.

An additional truck assembly system is featured in the model that includes truck-backhaul opportunities for cotton moving from originating warehouses in west Texas and Oklahoma to transloading warehouses in the Dallas-Ft. Worth intermodal terminal market areas and the Houston and Galveston port areas.

Important quantities of cotton move into the cotton export channel via railroad's inland intermodal terminals. This system is central to the movement of cotton to West Coast ports and, to a lesser extent, to East Coast ports. Comparatively small quantities of cotton are transported by railroad boxcars from selected originating warehouses to ports and border-crossing locations. Both rail transportation systems are featured in the developed spatial model of the U.S. cotton economy.

DATA

The following discussion regarding cotton supply and warehousing, and the transportation and logistics network relate to data incorporated into the spatial model while discussion pertaining to intermodal terminal investments and costs, roadway pavement costs, and CO_2 emission offer insight on data used in combination with the spatial model to accomplish study objectives.

Cotton Supply and Warehousing

The annual production of baled cotton was generated at the spatial model's gin plant sites based on plant capacity and cotton production in the crop reporting district where the gin plant was located. Carry-in cotton stocks were created at each warehouse based on regional carry-in stock data and warehouse storage capacity. In particular, a gin plant's annual output was determined by allocating a crop reporting district's production to area gin plants based on plant capacity. Temporal output of baled cotton at cotton gin plants was based on data from the regional cotton classing offices. A state's carry-in cotton stocks were distributed among state warehouses based on each warehouse's storage capacity and Intercontinental Exchange (ICE 2009) data on stored cotton at cotton future delivery points.

The gin plant population was obtained from the Cotton Board (2009), and proprietary information on historical gin plant capacity and output was obtained from a national cotton industry organization. The temporal ginning pattern in the various cotton production regions was approximated with the USDA's Agricultural Marketing Service (USDA 2009a) cotton classing office data. Cotton production data by crop reporting district was from the USDA's National Agricultural Statistical Service (USDA 2009d) while the USDA's Farm Service Agency (USDA 2009c) was the source of information on the cotton warehouse population and associated warehouse capacity. Data on carry-in cotton stocks were available from the U.S. Census Bureau's *Current Industrial Reports* (2009b) , the USDA's Economic Research Service *Cotton and Wool Yearbook 2009* (USDA 2009b), and the *Cotton Certified Stock Report* from the Intercontinental Exchange (ICE 2009). The Census Bureau's cotton carry-in stocks data by state were adjusted to reflect the USDA's national carry-in estimate. In addition, the Intercontinental Exchange's data on cotton storage stocks in each of the five cotton futures delivery markets (Galveston and Houston, Texas; Greenville, South Carolina; Memphis, Tennessee; New Orleans, Louisiana) was used to allocate carry-in stocks among delivery point warehouses based on the storage capacity of warehouses in each delivery market. The remaining cotton carry-in stocks in each state were allocated among those warehouses outside of the futures market delivery locations based on warehouse storage capacity.

Estimates of domestic cotton mill demand by state were obtained from the U.S. Census Bureau's *Current Industrial Reports* (2009a) on cotton consumption. Employment at broadwoven fabric mills and yarn spinning mills were used to estimate cotton consumption for the eleven sub-state domestic demand regions included in the national model. Data on employment at the U.S.'s broadwoven fabric and yarn spinning mills were taken from Manta (2009a, 2009b). Cotton exports via individual ports and border-crossing locations were from WISERtrade (2009) whose data are obtained from the U.S. Census Bureau's Foreign Trade Division.

Individual cotton warehouse handling and storage charges were obtained from a survey of Texas warehouses, Texas Cotton Association (2009), warehouse websites, and a proprietary list constructed by a national cotton industry organization. Warehouse charges were for receiving, storing and loading of baled cotton. The receiving charge at cotton warehouses averaged about \$3.50 per bale, as did the per bale load-out charge, while quarterly storage charges averaged about \$5.50 per bale.

Transportation and Logistics Network

The cotton transportation and logistics network featured in the national spatial model link the cotton gin plants to cotton warehouses, then linking warehouses to domestic mill demand regions, inland intermodal terminals, ports, border-crossing locations, and other warehouses (transloading warehouses) by quarterly transport rates. Further, the inland intermodal terminals are connected to selected ports in the national model. Truck transportation is central to movement of U.S. baled cotton. Cotton gin plants ship entirely by truck to warehouses. Warehouses ship large quantities by truck to domestic mill demand regions, ports, transloading warehouses, border-crossing locations, and inland intermodal terminals. Railroads transport large quantities of cotton in containers from selected inland intermodal terminal locations to port areas, while selected warehouses ship via boxcars to ports, domestic mill sites, and border-crossing locations.

Information on cotton trucking rates that link gin plants to warehouses was obtained by telephone survey of 263 Texas, Oklahoma, New Mexico, and Kansas cotton gin plant operators in 2008-2009. These data were used to estimate a rate-dependent equation, where rate was determined by distance of haul and binary variables that accounted for geographic regions and a distance zone. This equation was used to estimate all gin to warehouse routes in the national cotton model (Appendix A).

Texas and mid-south truck brokers, freight forwarders, and selected cotton merchants provided information on truck rates connecting warehouses to ports, domestic mills, transload facilities, and intermodal terminals. These data were used to estimate truck rate equations that were explained by distance of haul where distance was determined by the route that minimized the trucker's drive time. In addition, drayage charges between transloading facilities and inland intermodal terminals and dock side locations were provided by cotton industry personnel (Appendix A). The truck rate data used to estimate the rate equations and drayage charges were base rates or rates that did not reflect fuel surcharges. However, with scalars provided by industry personnel, the base truck rates, obtained from the estimated rate equations and the drayage charges, were adjusted to reflect fuel surcharges that were based on the U.S. Department of Energy's *Monthly Retail On-Highway Diesel Prices* (DOE 2009) for nine U.S. regions. The regional diesel price information allowed for estimation of truck rates and drayage charges that differed by U.S. region.

Railroad rate and routing information was obtained from the Surface Transportation Board's *Public Use Waybill* (STB 2009), selected cotton merchants, freight forwarders, and railroad company personnel. Some warehouses in the mid-south and Texas plains shipped small quantities of cotton by boxcar to Gulf ports and U.S.-Mexico border-crossing locations. In contrast, large quantities of containerized cotton were shipped from selected inland intermodal terminals to West Coast ports.

Intermodal Terminal Investment and Costs

To estimate the feasibility of an intermodal freight terminal in west Texas, it was necessary to estimate size of intermodal terminals that might be required to accommodate regional cotton export shipments to West Coast ports and then obtain information on the terminal's investment requirements and operation costs. Based on a survey of Texas cotton warehouses regarding shipments to various destinations, and regional cotton production trends, investment levels and costs were estimated for intermodal terminals that shipped 12,000; 14,000; 16,000; and 18,000 containers of cotton per year. Each container holds 88 cotton bales.

Estimated terminal dimensions, terminal investment requirements, and costs were largely based on previous studies. Stewart, Ogard and Harder (2004) examined intermodal terminal requirements in small and medium size communities and offered parameters useful in prescribing terminal yard dimensions, and associated railroad track. A study by the Michigan Department of Transportation and U.S. Department of Transportation (2008) provided insight on type and number of rail turnouts and costs, as well as information on parking. Loading space requirements came from Victoria Transport Policy Institute (2008). Personnel from Wilbur Smith Associates offered perspective on requirements regarding terminal lighting, lifters, tractors, chassis and employees based on their previous study efforts. Estimated costs of land for an intermodal terminal came from the website of the Lubbock Economic Development Alliance (2009) while a study by the Minnesota Department of Agriculture and Wilbur Smith Associates (2008) provided information on investment in truck scales, utilities, lifters, tractors and chassis. See Appendix Table B1 for estimated terminal dimensions and specifications, and Tables B2 and B3 for information on investment levels, and personnel requirements and expenses. Estimated investment in the 12,000; 14,000; 16,000; and 18,000 container per year terminals were \$7.92, \$8.82, \$9.79, and \$10.69 million, respectively.

The estimated investment in the 12,000; 14,000; 16,000; and 18,000 container per year terminals was amortized at 7% over a ten-year period. Information on depreciation expense, insurance expense, maintenance and repair costs, energy costs and taxes were partially based on a study by Berwick (2007) of the Upper Great Plains Transportation Institute who examined the feasibility of intermodal terminals in rural areas and offered insight on computation methods to estimate these costs. Based on the Berwick (2007) study and with selected computational adjustments for location and time period, the annual costs were estimated for the four intermodal terminal sizes. In contrast to the Berwick study that depreciated equipment and infrastructure for a 15 to 20 year period, annual depreciation expense associated with infrastructure and equipment in this study was calculated using a straight-line method over a 10-year time frame with an assumed salvage value of zero. Annual fixed costs for the 12,000; 14,000; 16,000 and 18,000- container-per-year terminals were estimated to be \$2.11, \$2.35, \$ 2.61, and \$2.85 million and when operating at capacity the estimated operating costs were \$0.86, \$0.91, \$1.02, and \$1.07 million. Total cost per handled container ranged from \$248 or \$2.81 per bale for the 12,000 container terminal to \$218 per container or \$2.48 per bale for the 18,000 container terminal (Appendix Table B4). However, if the focus were on annual cash outlay without consideration to depreciation expense, terminal costs range from \$182 per container or \$2.07 per bale for the 12,000 container terminal to \$159 per container or \$1.81 per bale for the 18,000 container terminal.

Roadway Pavement Cost

The introduction of an intermodal terminal in the intense cotton production region of west Texas is expected to reduce the quantity of cotton transported by truck from this region to existing intermodal facilities in Dallas-Ft. Worth but increase truck-transport into that potential intermodal site. To determine the effect of introducing an intermodal terminal in west Texas on total loaded truck-miles and pavement costs, it was necessary to estimate the change in loaded truck-miles that would result with introduction of the intermodal terminal as well as the marginal cost associated with pavement use. The change in total loaded truck-miles was approximated by contrasting spatial model solutions *ex ante* and *ex post* operation of the intermodal terminal in west Texas.

The change in total pavement cost that results with introduction of the intermodal terminal was estimated by using the Federal Highway Administration's (FHWA) functional classification guidelines (USDOT 2000) to approximate miles traveled over each functional system and by updating related marginal pavement cost parameters. Marginal pavement cost for the rural interstate highway (12.7 cents for 80,000-pound, five axle truck) was taken from the FHWA's *Federal Highway Cost Allocation Study* (USDOT 2000). Previous estimates of pavement cost for principal and minor arterials and collectors were provided by Dr. Denver Tolliver of the Upper Great Plains Transportation Institute. The collected pavement costs were subsequently updated with the FHWA's *Construction Cost Trends for Highways, Table PT-1* (USDOT 2010) and the FHWA's *Price-Trends for Federal Aid Highway Construction* (USDOT 2006). Interestingly, the Construction Cost Index increased nearly 40 percent from 2000 to 2006 but by 2009 the Index had declined to take on a value about 10 per cent larger than the 2000 Index. After consideration of federal and state fuel taxes (44.4 cents per gallon) and an estimated 5.5 miles per gallon fuel efficiency, the uncompensated marginal costs per loaded truck-mile were estimated for an 80,000 pound, five-axle truck on the (1) interstate ($0.059), (2) principal arterial ($0.259), (3) minor arterial ($0.359), and (4) collector ($0.876) roadways.

CO_2 Emission

Introduction of an intermodal terminal in the intense cotton production region of west Texas is expected to reduce CO_2 emission because of the reduced need to truck-transport cotton to distant intermodal terminals in Dallas-Ft. Worth. To approximate the likely reduction in CO_2 emission that may result with an intermodal terminal in west Texas, it was necessary to estimate emission *ex ante* and *ex post* the studied intermodal terminal in west Texas. This was accomplished by contrasting cotton model outcomes regarding truck mileages, and using estimated parameters relating to CO_2 emission and truck fuel use during loaded and empty hauls.

Dr. Josias Zietsman of the Center for Air Quality Studies at the Texas Transportation Institute provided a per mile CO_2 emission rate for loaded Class 8 trucks operating at average speeds: the emissions rate was estimated with MOVES2010 which is the Environmental Protection Agency's state-of-the-art tool (EPA 2010). At an assumed average speed of 55 miles per hour, the Class 8 truck has an estimated CO_2 emission rate of 2003.7 grams/loaded mile. For empty truck mileage, the emission rate was adjusted downward in proportion to reduced fuel consumption. Franzese, Knee and Slezak (2009) estimate the effect of load size and truck-tire configuration on fuel efficiency of class 8 trucks. Their analyses suggest the reasonableness of the rule-of-thumb "each additional 10,000 pounds of payload decreases fuel economy about 5 percent." Further, the Federal Railroad Administration's *Final Report: Comparative Evaluation of Rail and Truck Fuel Efficiency on Competitive Corridors* (USDOT 2009) indicate the reasonableness of this rule-of-thumb. Based on these data, the CO_2 emission rate per loaded truck-mile was estimated to be 2003.7 grams and 1615.8 grams per empty truck-mile.

Introduction of an intermodal terminal in west Texas will require the railroad to relocate empty containers from the Dallas-Ft. Worth complex to the west Texas terminal. It is assumed that the net effect of this rail activity is neutral regarding CO_2 emission. *Ex ante* the west Texas terminal, truck-transported west Texas cotton would be routed to Dallas-Ft. Worth to be placed in containers for shipment to West Coast ports. This containerized cotton will pass through west Texas on its route to West Coast ports. *Ex post* the west Texas facility, empty containers will be routed by railroad to west Texas and then loaded for shipment to West Coast ports. Thus, the affected mileage that the rail-transported container travels is little altered by introduction of an intermodal terminal in west Texas. For this reason, it was assumed that railroad CO_2 emission would not be significantly affected by the introduction of the intermodal terminal.

Truck brokers and cotton shippers indicate important quantities of cotton move from west Texas to Dallas-Ft. Worth intermodal terminals that involve a truck, chassis and container (source-loaded). Typically, the container is empty when departing the intermodal facility, therefore for all CO_2 computations it was assumed that one-half of the round-trip mileage associated with source-loaded cotton involves empty truck-miles. Further, based on information from a truck broker it was assumed that all truck-transported cotton moving via a van or flatbed into Dallas-Ft. Worth involves a backhaul percentage of 50 percent.

COTTON MODEL VALIDATION AND METHOD OF ANALYSIS

Model Validation

To develop confidence in the spatial model of the cotton economy, model solution output was contrasted with actual or real-world information. The national model of the U.S. cotton industry features detail on regional cotton production and domestic and international cotton demands for the 2008-2009 crop year (August 1 – July 31). Further, the spatial model includes all U.S. cotton gins, cotton warehouses, transloading warehouses, relevant intermodal terminals, and ports with linking transport modes and associated handling, storage, and transportation charges and rates. The output from the spatial model identifies cotton flows through cotton warehouses, transloading warehouses, intermodal terminals and port areas that minimize cotton handling, storage and transportation charges subject to regional cotton supplies, regional domestic cotton mill demands, and international demands as represented at port areas and border-crossing sites. The solution to the developed spatial model with its associated cotton flows and costs was contrasted with secondary cotton flow data for 2008-2009 to develop confidence in the model and its ability to correctly project flows and costs. Initial model-generated solutions showed quarterly and annual carryover stocks to be misrepresented in various regions but, with counsel of industry experts and additional data, the model was successfully altered. In the final analysis, the base model solution representing the 2008-2009 crop year revealed cotton flows and costs that closely approximated reality, hence the model was judged capable of accomplishing study objectives.

Procedure to Determine Feasibility of Investment in Intermodal Terminal

The spatial model was central to determining the economic feasibility of an intermodal facility in the intensive cotton production region of west Texas. First, the costs and charges of assembling cotton from nearby gins and warehouses to the hypothetical intermodal terminal site in Lubbock, Texas were introduced into the spatial model in conjunction with the estimated charges of shipping the rail-transported containers of cotton from the potential terminal to West Coast ports. After introduction of these costs and charges, the least-cost model was solved to determine the quantities of cotton that would be assembled to the potential terminal site under alternative intermodal terminal tariffs or prices; this offered insight into the potential terminal's annual revenues. The information on quantities of cotton assembled to the intermodal site at alternative prices or tariffs was subsequently examined in conjunction with the estimated costs associated with operating an inland intermodal facility that annually ships 12,000; 14,000; 16,000 and 18,000 containers per year to identify the profitability of the hypothetical terminal. This heuristic analysis permits an estimate of the breakeven volume for each terminal and its expected revenues, costs and profits.

Currently a small, private intermodal facility operates in Lubbock. Based on discussions with industry personnel and an area planner, it was assumed that this facility would cease to operate if a new expanded terminal were constructed. Hence, the feasibility analysis assumes the existing intermodal facility is not in operation.

Because variability of cotton production in the west Texas plains was thought to affect the economic feasibility of the intermodal terminal, analyses were carried out to examine the sensitivity of the terminal's feasibility to variation in cotton production. Analyses showed cotton production in the Texas plains in the 2008-2009 crop year (base year for model) to be slightly below the average production over the past decade, therefore, cotton production in Texas crop reporting districts 11, 12, 21, 22 and 70 was adjusted upward in the base model to reflect the historic average over the past decade. To examine variability of cotton production on intermodal terminal feasibility, production levels in applicable crop reporting districts were scaled to reflect historic production and the spatial model subsequently solved to estimate quantity of cotton attracted to the hypothetical Lubbock terminal under alternative prices or charges. This revenue information in combination with costs for the 12,000; 14,000; 16,000 and 18,000 container terminals was used to evaluate the effect of variable cotton production levels on economic feasibility of the hypothetical terminal.

The effect of introducing containerized cotton shipments from a nearby intermodal terminal (Amarillo, Texas) was thought to unfavorably influence the feasibility of the hypothetical Lubbock terminal. Therefore, additional analysis was carried out. To evaluate competition from the existing intermodal terminal in Amarillo, Texas the charges of assembling cotton from gins and warehouses to this competing site were included in the spatial model as were the estimated costs of shipping containerized cotton from this location to West Coast ports. After the introduction of these costs, the least-cost spatial model was solved to determine the quantities of cotton assembled to the hypothetical intermodal terminal (Lubbock, Texas) and the competing site (Amarillo, Texas) at alternative tariffs. This procedure offered insight into the sensitivity of the Lubbock facility to the nearby competition in Amarillo.

Procedure to Determine Effect of Intermodal Terminal on Roadway Pavement Cost

The introduction of an intermodal terminal in the intensive cotton production region of west Texas was expected to reduce truck-transported cotton movement from west Texas to the Dallas-Ft. Worth intermodal terminals but increase flow to the supposed terminal in Lubbock, Texas. The spatial model output and marginal pavement costs by functional highway classes were central to estimating the effect of an intermodal terminal in west Texas (Lubbock) on roadway pavement costs.

The spatial model output that denoted the origin and destination of all truck hauls, in combination with a roadway routing tool that identifies the associated highway names and mileages was used to approximate distance by functional roadway classification. The *FHWA Functional Classification Guidelines* (USDOT 2000) were followed to approximate mileages by principal arterials, minor arterials and collectors, with the principal arterials subdivided into the interstate system and other principal arterials. This information, in combination with the associated uncompensated marginal pavement costs (loaded truck-mile cost), facilitated estimation of roadway pavement cost *ex ante* and *ex post* introduction of the intermodal terminal. By summing pavement costs for all involved roadways in the two solutions and contrasting the summed estimate of pavement costs, the potential effect of the hypothetical intermodal facility on roadway pavement cost was approximated. All analyses with the spatial model were carried out when regional cotton production (crop reporting districts 11, 12, 21, 22 and 70) reflected average production during the most recent decade (2000-2009).

The optimization method and associated procedure used to estimate truck mileages *ex ante* and *ex post* introduction of the intermodal terminal in west Texas implied that trucks will tend to follow the least-cost routing in the very short-run. This procedure abstracted from a phased-in truck traffic pattern that may be more realistic, therefore, the measured reduction in pavement deterioration may be over-stated in the short-run.

Procedure to Determine Effect of an Intermodal Terminal on CO_2 Emission

The effect of introducing an intermodal terminal in Lubbock, Texas on CO_2 emission by the truck mode was accomplished with spatial model output that relates truck mileage *ex ante* and *ex post* introduction of the intermodal terminal in west Texas. In addition, truck CO_2 emission rates (when trucks were loaded and empty) and truck backhaul percentages were utilized in calculation of CO_2 emissions. Analyses focused on truck mileage associated with the assembly of cotton to applicable intermodal terminals (Lubbock, Dallas-Ft. Worth). All analysis with the spatial model was carried out when regional cotton production (crop reporting districts 11, 12, 21, 22 and 70) reflected average production during past decade (2000-2009).

Tol (2005) studied peer-reviewed articles that estimated the marginal damage cost of CO_2 emission and concluded its mean value to be $43 per metric ton. This value was used to offer an approximation to the value of CO_2 removed through introduction of an intermodal terminal in west Texas.

The procedure to estimate the reduction in CO_2 emission failed to consider a phased-in truck traffic pattern, therefore, measured reductions in CO_2 emission and the associated value of the reduced emission may be overstated in the short-run.

RESULTS

Feasibility of Intermodal Terminal

Initial analyses with the spatial model projected quantities of cotton transiting the hypothetical Lubbock, Texas intermodal terminal when the facility levied a tariff of $1, $2, $3, $4 and $5 per bale. The per bale charge introduced into the spatial model was in addition to costs associated with assembling cotton from area gins and warehouses to the proposed intermodal terminal site in Lubbock (source-loaded and flatbed/van assembly systems) and the shipment of this cotton to West Coast ports on double-stack railroad cars.

Analysis with the spatial model projected an estimated 3.57 million bales would be handled by the supposed intermodal terminal in Lubbock if $1 per bale were charged by the terminal. When the charge was adjusted to $2 per bale the volume handled by the hypothetical terminal declined to 3.08 million bales, and, when the charge was $3, $4 and $5 per bale, the associated quantities were 2.58, 2.02 and 0.538 million bales, respectively.

The 12,000 container intermodal terminal had a projected annual capacity of approximately 1.06 million cotton bales (88 bales per container) while the estimated 14,000; 16,000 and 18,000 container terminals had projected annual capacities of 1.23, 1.41, and 1.58 million bales, respectively. The above analyses showed that the projected quantities of baled cotton handled by the hypothetical Lubbock terminal at charge of $1 (3.57 million bales), $2 (3.08 million bales), $3 (2.58 million bales), and $4 per bale (2.02 million bales), exceeded the capacity of the four evaluated intermodal terminals. Further, the analyses indicated the $4 per bale charge or $352 per container charge maximizes intermodal terminal revenues ($4 per bale x 2.02 million bales = $8.08 million).

The estimated total annual cost associated with investment and operation of the 12,000; 14,000; 16,000 and 18,000 container terminals is shown in Table B4 (Appendix B). When the evaluated intermodal terminal is assumed to levy a charge of $352 per container or $4 per bale, the estimated breakeven volumes for the 12,000; 14,000; 16,000; and 18,000 container terminals are 7,539; 8,211; 9,061; and 9,758 containers per year, respectively (Table 1). All containers are assumed to be 40-foot marine containers (FEU). When the terminal operates at capacity, the expected returns above specified costs for the four analyzed terminals (12,000; 14,000; 16,000 and 18,000 container terminals) are an estimated $1.25, $1.66, $2.00, and $2.41 million respectively. The estimated rate of return for each terminal size was estimated by dividing its estimated return by total terminal investment in Table B2. The estimated rates of return on investment were estimated to be 15.8%, 18.8%, 20.4% and 22.5%, respectively (Table 1).

Sensitivity of Intermodal Terminal's Feasibility to Variable Production Levels

After including alternative cotton production levels into the spatial model, the model with inclusion of all handling and transportation costs associated with the hypothetical Lubbock terminal and the $4 per bale charge ($352 per container) was solved to determine quantity of cotton attracted to the terminal site. The analysis showed at the high production levels of 2005 and 2007 (7.0 million bales) the Lubbock terminal would attract about 2.66 million bales whereas at low production of about 2.54 million bales (2000 production) approximately 1.7 million bales would transit the Lubbock terminal. These analyses suggested the largest of the examined intermodal terminals (18,000 containers per year or 1.58 million bales) would have ample cotton supplies to operate at full capacity in all years during 2000-2009.

Sensitivity of Intermodal Terminal's Feasibility to a Competing Intermodal Terminal

Additional analysis was carried out to determine if operation of an existing intermodal terminal in Amarillo, Texas as a cotton shipping terminal would affect the economic feasibility of the studied Lubbock, Texas terminal. Amarillo is approximately 120 miles north of Lubbock and is at an extended distance from the intensive cotton production area surrounding Lubbock. Regardless, the USDA's Farm Service Agency (USDA 2009c) showed a large cotton warehouse to operate in Amarillo. Further, Amarillo is located on the Burlington Northern (BNSF) railroad line that connects the Chicago, Illinois area to southern California, a route which transports empty containers from the Midwest to California, hence, the possible opportunity to efficiently route empty containers into the Amarillo, Texas terminal.

To evaluate the potential effect of cotton shipments through the competing Amarillo intermodal terminal, that edition of the spatial model featuring an intermodal terminal in Lubbock was modified to allow assembly of cotton to Amarillo from area gins and warehouses and its shipment to West Coast ports. The modified model reflected flatbed/van costs of trucking into an Amarillo transloading warehouse and associated drayage charges to the Amarillo intermodal terminal as well as a source-loaded assembly system involving truck, container and chassis. Further, the modified model included a charge by the existing terminal in Amarillo for container handling and lifts, and an estimated railroad rate to West Coast ports.

Table 1: Estimated Annual Revenues and Costs for 12,000; 14,000; 16,000; and 18,000 Containers/Year Intermodal Terminal Operating at Lubbock, Texas

	Containers per Year (FEU) 12,000	Containers per Year (FEU) 14,000	Containers per Year (FEU) 16,000	Containers per Year (FEU) 18,000
Fixed Cost[1] ($)	2,113,466	2,354,044	2,613,110	2,853,593
Management, Employee and Other Expenses[1] ($)	860,080	914,001	1,017,978	1,072,030
Total Cost ($)	2,973,546	3,268,045	3,631,088	3,925,623
Total Revenue[2] ($)	4,224,000	4,928,000	5,632,000	6,336,000
Breakeven Volume (Containers)	7,539	8,211	9,061	9,758
Returns above Specified Costs[3] ($)	1,250,454	1,659,955	2,000,912	2,410,377

[1] From Table B4 in Appendix B.
[2] Analyses with spatial model shows operator of terminal has the ability to charge up to $4/bale and attract 22,728 containers (2 million bales) to the intermodal facility under average production levels in region.
[3] Total Cost does not reflect federal corporation taxes.

Analysis showed that operation of the Amarillo intermodal facility as a cotton shipping site has negative implications for investment into the hypothetical Lubbock terminal. If the source-loaded assembly system (truck, container and chassis) operating about Lubbock and Amarillo was limited to a distance of 50 miles and the flatbed/van system was without distance restrictions, the Lubbock intermodal terminal volume would decline modestly to about 1.9 million bales from 2.02 million bales ($4 per bale tariff), with an estimated quantity through Amarillo of 0.147 million bales. However, if Amarillo and Lubbock had a source-loaded assembly system operating at a distance of 100 miles, Lubbock's hypothetical intermodal terminal experienced a precipitous loss in volume handling an estimated 0.76 million bales while the Amarillo terminal increases to 1.69 million bales. And, as expected, if the Amarillo terminal imposed a charge, the region's cotton production shifted back to the Lubbock terminal. For example, if Amarillo introduced a charge of $1 per bale, the Amarillo volume declined to 1.64 million bales; when a charge of $2, $3, or $4 per bale was levied, Amarillo terminal volume declined to an estimated 1.42, 0.80, and 0.12 million bales, respectively. And, as the Amarillo's terminal volume declined at charges of $2, $3, and $4 per bale, the Lubbock terminal's volume increased to 0.85, 1.29, and 1.93 million bales.

Analysis indicates that investment in the Lubbock intermodal terminal may be vulnerable if the existing intermodal terminal in Amarillo were to become a competing cotton handling and shipping site. The investment required to construct and operate the hypothetical facility in Lubbock places it at a competitive disadvantage relative to the existing intermodal terminal in Amarillo.

Effect of Intermodal Terminal on Annual Roadway Pavement Costs

The feasibility analysis showed that an intermodal terminal in the Lubbock, Texas area could annually attract about 2 million bales. Based on analysis with the spatial model, an estimated 5.27 million loaded truck-miles would be associated with assembly of cotton to the hypothetical Lubbock terminal and to the existing intermodal terminals in Dallas-Ft. Worth if the Lubbock facility were implemented. Further, approximately 50% of these loaded truck-miles would be over other principal arterials, 37% over the interstate system, 10% over minor arterials, and 3% via collector roadways. And, based on the estimated marginal pavement cost parameters, total annual uncompensated pavement cost would be $1.11 million.

To determine the approximate reduction in roadway pavement cost resulting from introduction of the intermodal terminal in Lubbock, it was necessary to measure loaded truck-miles expended with the current cotton transportation system. Unfortunately, measurement of loaded truck-miles with the current cotton transportation system was not straight-forward because of a private cotton terminal operator in Lubbock who shipped an unknown number of cotton-filled containers to West Coast ports. It is estimated by trade sources that the private intermodal operation annually ships from 500,000 to 750,000 cotton bales. Therefore, these values were assumed when calculating loaded truck-miles with the current cotton transportation system.

When the private operator in Lubbock handled 500,000 bales, it was estimated that 9.80 million loaded truck-miles would be expended in assembling cotton to the intermodal terminals in Lubbock and Dallas-Ft. Worth, and, when that existing Lubbock operation handled 750,000 bales, total loaded truck-miles declined to 9.02 million. The corresponding annual pavement cost associated with shipment of 500,000 bales via Lubbock is an estimated $2.26 million and, with 750,000 bales, an estimated $2.08 million. Based on these estimated values, introduction of the hypothetical intermodal terminal in Lubbock annually reduced uncompensated pavement cost from $0.97 million ($2.08 – $1.11 = $0.97) to $1.15 million ($2.26 - $1.11 = $1.15).

Effect of Intermodal Terminal on CO_2 Emission

Analyses show introduction of an intermodal terminal in Lubbock that handled approximately 2 million bales of cotton would reduce CO_2 emission associated with truck assembly of cotton to intermodal terminals in Lubbock and Dallas-Ft. Worth by 42 to 47 percent relative to the current system. Total annual CO_2 emission attributable to truck assembly is estimated to be 38,667 short tons when the private operator in Lubbock handles 500,000 bales and truck-assembled cotton to Dallas-Ft. Worth terminals is included in the CO_2 computation, and estimated to be 35,566 short tons when the current Lubbock operator expands volume to 750,000 bales. If the intermodal terminal in Lubbock were implemented (2 million bales), total CO_2 emission would decline to 20,588 short tons; this yields reductions in CO_2 emission that range from 14,978 (35,566 – 20,588=14,978 short tons) to 18,079 (38,667 - 20,588 = 18,079 short tons) short tons/year. Based on Tol's estimate regarding the marginal cost of CO_2 ($43 per metric ton), the estimated annual value of reduced CO_2 emissions range from $0.584 to $0.705 million per year.

CONCLUSIONS

This study examines the economic feasibility of investment in an intermodal terminal in west Texas and explores its implications for reducing roadway maintenance costs and CO_2 emission. The study focuses on cotton, a leading agricultural commodity in Texas, which is highly dependent on the international market and truck transport from west Texas to the Dallas-Ft. Worth metroplex for purposes of accessing containerized railroad transportation to West Coast ports. Conceptually, an intermodal terminal in west Texas would allow cotton to access the intermodal system near its production location, removing the need for truck transport into the Dallas-Ft. Worth metropolitan area. Because the assembly of cotton into the Dallas-Ft. Worth railroad hubs is at distances up to 335 miles, truck-miles and roadway maintenance may be significantly decreased as would CO_2 emissions with the introduction of rural intermodal terminals.

Much of the analysis in this study was accomplished with a spatial model representing the U.S. cotton industry. The least-cost model features cotton handling, storage and transport activities that link cotton gins to warehouses and ultimately to intermodal terminals, domestic textile mills and U.S. port areas. Domestic cotton demand is represented in regions that feature textile mills and foreign demand is represented at U.S. cotton ports. All U.S. cotton gins (811) and warehouses (452) in operation during the 2008-2009 crop year are featured in the model. The developed spatial model includes considerable detail regarding cotton transportation and logistics.

The analyses show an intermodal terminal in west Texas' intensive cotton production region (Lubbock, Texas) to be economically viable. It is estimated that the facility could attract about 2 million bales or nearly 30% of Texas' average cotton production. The largest intermodal terminal examined in this study (18,000 container shipments/year or 1.58 million bales) would require an investment of $10.69 million and would be expected to earn a rate of return on investment exceeding 20 percent. Additional analyses show the 18,000 container per year terminal would attract profitable volumes during the region's lowest cotton production years, but would be vulnerable if an existing intermodal terminal at a nearby location (Amarillo, Texas) were to commence cotton shipments to West Coast ports.

Implementation of an intermodal terminal in west Texas that handles approximately 2 million cotton bales is estimated to reduce truck (80,000 pound, 5-axle) travel on state roadways an estimated 3.75 to 4.53 million loaded truck-miles and lower annual pavement expenditure approximately $1 million. This positive externality suggests an opportunity for public and private sector cooperation. Further, the reduced truck-miles expended to assemble Texas cotton to intermodal facilities is estimated to reduce CO_2 emissions by 42 (14,978 short tons) to 47 (18,079 tons) percent relative to the current marketing system. The estimated value of reduced CO_2 emissions ranges from $.580 to $.699 million per year. Finally estimated traffic into the Dallas-Ft. Worth metroplex would be reduced by 13,800 to 16,700 trucks per year with introduction of the west Texas intermodal terminal.

In summary, the analysis suggests that investments in intermodal terminals in rural areas may offer opportunities to improve marketing system efficiency and, reduce roadway maintenance costs and vehicle emissions.

APPENDIX A: TRUCKING COST

Appendix A offers information on trucking and drayage charges included in the developed spatial cotton model. Included are estimated truck rate equations linking (1) gins to warehouses and (2) warehouses to ports, mills, transloading facilities, border-crossing sites and other locations. Included is information on charges associated with source-loaded cotton transported from warehouse to inland intermodal terminal and dockside terminal, and drayage of cotton from transloading warehouse to inland intermodal terminal and dockside terminal. In addition, discussion is offered regarding truck fuel-surcharges.

Table A1 includes the definition of variables in the four estimated truck rate equations and Table A2 includes the estimated equations. The gin to warehouse truck rate equation was estimated by ordinary least squares and included 221 observations: the associated adjusted R-square for this equation was 0.86 and all explanatory variables were highly significant except one. The truck rate equation representing shipments from warehouses to ports and inland transloading warehouses included 48 observations and an adjusted R-square of 0.89 with all explanatory variables significant at 1 percent level. The equation used to estimate truck rates when cotton was the backhaul had an adjusted R-square of 0.72, and the explanatory variables were highly significant: the equation was based on 16 observations. The truck rate equation representing shipments from warehouses to mills, border-crossing locations and other sites was based on 48 observations: the estimated equation had an adjusted R-square of 0.93.

Source-loaded cotton refers to the direct shipment of cotton in a marine container from an originating warehouse to an inland intermodal terminal or a dockside terminal. The empty container is towed on a chassis from a terminal (inland or port area intermodal terminal) to the cotton warehouse in the production region where the container is loaded and towed to either an inland intermodal terminal or a dockside terminal. These source-loaded rates include a per mile charge times the round-trip distance plus a fuel-surcharge. Based on conversations with brokers and freight forwarders, the rate was estimated to be $1.30 per mile for all source-loaded shipments except for those to inland terminals in Dallas-Ft. Worth and the west Texas area (Lubbock, Texas) where the rate was $1.10 per mile.

Truck fuel-surcharges were not applicable for estimated gin to warehouse movements since fuel surcharges were included in the estimated rate. In addition, the rate equation representing cotton as a backhaul did not include fuel surcharges since these charges were not paid for this type of haul. The remaining truck rate equations were estimated from base rates or rates without fuel surcharges. The fuel surcharge was incorporated by an upward adjustment in the base rate. For example, if the current No.2 diesel price were in a range of $2.20 to $2.30 per gallon, the surcharge was 12% which would involve a 12% increase in the base rate.

Drayage service is required to move the cotton-filled containers to an inland intermodal terminal or a dockside terminal. Cotton that has been drayed to an inland intermodal terminal is typically placed on double-stack container cars for shipment to selected East Coast and West Coast ports while cotton assembled to dockside will ultimately be loaded on a container ship for export. Source-loaded cotton is loaded into a container at an originating cotton warehouse in the cotton production region and does not require drayage since the loaded container moves directly to the inland intermodal terminal or dockside terminal. The collected drayage fees ranged from $150 to $250 per container and typically included a fuel surcharge. Finally, the charge for intermodal terminal lifts is estimated to be $1.14 per bale or $100 per container.

Table A1: Definition of Variables in Truck Rate Equations

Table A1.1: Gin to Warehouse Equation.

Variables	Definition
Rate	Truck rate in $/bale/mile
Miles	One-way miles of haul
<200 miles	0,1 variable for hauls less than 200 miles
South Texas	0,1 variable for hauls that originate in South Texas
East Central Texas	0,1 variable for hauls that originate in East Central Texas
OKNM	0,1 variable for hauls that originate in Oklahoma and New Mexico

Table A1.2: Warehouse to Port and Transload Center Equation.

Variables	Definition
Rate	Truck rate in $/bale/mile
Miles	One-way miles of haul

Table A1.3: Warehouse Shipment (backhaul rate) Equation.

Variables	Definition
Rate	Truck rate in $/bale/mile
Miles	One-way miles of haul

Table A1.4: Warehouse Shipments to Border, Mill and Other Sites.

Variables	Definition
Rate	Truck rate in $/bale/mile
Miles	One-way miles of haul
LKan	0,1 variable for hauls originating from a Liberal, Kansas warehouse

Table A2: Estimates for Truck Rate Equations

Table A2.1: Gin to Warehouse Equation.

Variable	Coefficient	T-statistics
Intercept	1.2522	14.05***
Miles	0.0248	27.21***
<200 miles	-0.7984	2.11**
South Texas	0.4267	2.45***
East Central Texas	0.6894	2.97**
OKNM	0.3071	1.45

Table A2.2: Warehouse to Port and Transload Center Equation.

Variable	Coefficient	T-statistics
Intercept	2.6611	10.22***
Miles	0.0101	19.46***

Table A2.3: Warehouse Shipment (backhaul rate) Equation.

Variable	Coefficient	T-statistics
Intercept	3.5121	6.89***
Miles	0.0101	6.38***

Table A2.4: Warehouse Shipments to Border, Mill and Other Sites Equation.

Variable	Coefficient	T-statistics
Intercept	2.7767	12.56***
Miles	0.0096	20.25***
LKan	3.9634	9.27***

***significant at 1% level
** significant at 5% level

APPENDIX B: INTERMODAL TERMINAL METRICS AND COSTS

Table B1: Intermodal Terminal Metrics for Alternate Terminal Sizes (12,000; 14,000; 16,000; 18,000 containers/year).

Metrics for Infrastructure and Equipment	Containers per Year (FEU) 12,000	Containers per Year (FEU) 14,000	Containers per Year (FEU) 16,000	Containers per Year (FEU) 18,000
Containers/week	231	270	308	346
Lifts/week	462	540	616	692
Acres in Terminal Yard				
Acres (2000 lifts/acre)[1]	12	14	16	18
Square Feet/ Acre	43,560	43,560	43,560	43,560
Total Square Feet	522,720	609,840	696,960	784,080
Terminal Yard Parking Space				
Parking spaces (100 lifts/parking space)[2]	240	280	320	360
Square Feet/Parking Space	750	750	750	750
Total Parking Area (Sq. Ft.)	180,000	210,000	240,000	270,000
Parking Area (Acres)	4.13	4.82	5.51	6.20
Track				
Rail Loading Track (feet)[1]	1,600	1,866	2,133	2,400
Rail Car Storage Track (feet)	3,200	3,732	4,266	4,800
Total Track (feet)	4,800	5,598	6,399	7,200
Rail # 10 Turnout (number)[3]	2	2	2	2
Rail # 15 Turnout (number)[3]	2	2	2	2
Fencing				
Fencing (Linear Feet)	2,892	3,124	3,339	3,542
Lights				
Lights (number)[4]	5	6	7	8
Lifters				
Primary Lifter (number)	1	1	1	1
Backup Lifter (number)	1	1	1	1
Tractors				
Hostler Tractor[5]	2	2	3	3
Chassis				
Chassis[6]	4	4	6	6

[1] Stewart. R., L.Ogard, and F. Harder and R. (2004).
[2] Victoria Transport Policy Institute, (2008).
[3] Michigan Department of Transportation and USDOT, (2008).
[4] One light per 300 feet of loading space.
[5] One tractor per 12,000 lifts.
[6] Two chassis per tractor.

Table B2: Intermodal Terminal Investment Costs for Alternate Terminal Sizes (12,000; 14,000; 16,000; and 18,000 containers/year).

Terminal Land, Yard and Equipment Costs	Containers per Year (FEU) 12,000	Containers per Year (FEU) 14,000	Containers per Year (FEU) 16,000	Containers per Year (FEU) 18,000
Land in Terminal Yard				
Acres (number)	12	14	16	18
Land cost/acre ($)[1]	4,000	4,000	4,000	4,000
Total land cost ($)	48,000	56,000	64,000	72,000
Terminal Yard				
Grading Cost/cubic yard ($)[2]	10	10	10	10
Total grading cost ($)	580,800	677,600	774,400	871,200
Paving cost/square yard ($)[2]	40	40	40	40
Total paving cost ($)	2,323,200	2,710,400	3,097,600	3,484,800
Security fencing ($/foot)[2]	28	28	28	28
Silt fencing ($/foot)	2	2	2	2
Total fencing cost ($)	86,759	93,711	100,181	106,258
Lights required	5	6	7	8
Cost/light ($)[2]	35,000	35,000	35,000	35,000
Total light cost ($)	175,000	210,000	245,000	280,000
Total track (feet)	4,800	5,598	6,399	7,200
Cost/foot ($)[2]	200	200	200	200
Total track cost($)	960,000	1,119,600	1,279,800	1,440,000
Total turnout cost ($)[2]	480,000	480,000	480,000	480,000
Roadway access/exit cost ($)	380,000	380,000	380,000	380,000
Building cost ($)[2]	215,000	215,000	215,000	215,000
Truck scale cost ($)[3]	65,000	65,000	65,000	65,000
Utilities investment costs ($)[3]	65,000	65,000	65,000	65,000
Total terminal yard costs ($)[1]	5,330,759	6,016,311	6,701,981	7,387,258
Total land and yard cost ($)[2]	5,378,759	6,072,311	6,765,981	7,459,258
Engineering/Contingencies (30%)[4]	1,613,628	1,821,693	2,029,794	2,237,777
Total land, yard, and contingencies costs($)	6,992,387	7,894,004	8,795,775	9,697,035
Terminal Equipment costs				
Primary lifter cost ($)[3]	540,000	540,000	540,000	540,000
Backup lifter cost ($)[3]	250,000	250,000	250,000	250,000
Hostler tractor cost ($)[3]	115,214	115,214	172,821	172,821
Chassis cost($)[3]	23,040	23,040	34,560	34,560
Total equipment cost ($)	928,254	928,254	997,381	997,381
Total Terminal Investment Costs ($)	7,920,641	8,822,258	9,793,156	10,697,416

[1]Lubbock Economic Development Alliance (2008).
[2]Michigan Department of Transportation and USDOT, (2008)
[3]Minnesota Department of Agriculture and Wilbur Smith Associates.(2008)
[4]Ten percent attributable to engineering and remaining 20% are contingencies

Table B3: Intermodal Terminal Management/Employee Costs for Alternate Terminal Sizes (12,000; 14,000; 16,000; 18,000 containers/year).

Management and Employee Requirements and Costs	Containers per Year (FEU) 12,000	Containers per Year (FEU) 14,000	Containers per Year (FEU) 16,000	Containers per Year (FEU) 18,000
Gate employees (number)[1]	4	4	4	4
Yard employees (number)[2]	3	3	4	4
Total employees (number)	7	7	8	8
Total salary employee cost($)[3]	196,000	196,000	224,000	224,000
Manager's salary ($)[4]	51,000	51,000	51,000	51,000
Total salary expense($)	247,000	247,000	275,000	275,000
Benefits (30% of salary) ($)	74,100	74,100	82,500	82,500
Total salary and benefits ($)	321,100	321,100	357,500	357,500
Incidental expenses (% of compensation)	28%	28%	28%	28%
Total Manager and Employee Expense ($)	411,008	411,008	457,600	457,600

[1] Facility operates 24 hours/day and 7 days/week.
[2] Each employee can handle 12,000 lifts per year.
[3] Internet site: http://www.salary.com/warehouse workers (Accessed June 22, 2010).
[4] Internet site: http://www.salary.com/Intermodal Manager Job Listing (Accessed June 22, 2010).

Table B4: Estimated Annual Costs for Alternate Terminal Sizes (12,000; 14,000; 16,000; and 18,000 containers/year).

Costs	Containers per Year (FEU) 12,000	Containers per Year (FEU) 14,000	Containers per Year (FEU) 16,000	Containers per Year (FEU) 18,000
Fixed Cost				
Amortized cost($)[1]	1,103,584	1,229,207	1,364,482	1,490,057
Depreciation($)[2]	792,064	882,226	979,316	1,069,440
Insurance expense on infrastructure/equipment($)[3]	59,405	66,166	73,449	80,208
Taxes($)[4]	158,413	176,445	195,863	213,888
Total ($)	2,113,466	2,354,044	2,613,110	2,853,593
Management and employee salary cost				
Managers Salary($)[5]	51,000	51,000	51,000	51,000
Employee Salary($)[6]	196,000	196,000	224,000	224,000
Manager/employee fringe benefits($)[6]	74,100	74,100	82,500	82,500
Incidental expense($)[7]	89,908	89,908	100,100	100,100
Total ($)	411,008	411,008	457,600	457,600
Other Expenses				
Fuel and energy($)[8]	53,040	61,880	70,720	79,560
Maintenance and repair expense($)[9]	396,092	441,113	489,658	534,870
Total ($)	449,072	502,993	560,378	614,430
Total Annual Cost($)	2,973,546	3,268,045	3,631,088	3,925,621
Total Cost/Container($)	247.79	233.43	226.94	218.08
Total Cost/Bale($)	2.815	2.65	2.58	2.48

[1]Total investment in infrastructure and equipment amortized at 7% interest rate over a 10-year time period.
[2]Calculated by straight-line depreciation method with estimated life of 10 years and zero salvage value.
[3]Calculated to be 0.75% of total investment in infrastructure and equipment. Based on Berwick (2007), with adjustments made for location, time period, and equipment complement.
[4]Estimated to be 2% of total infrastructure and equipment.
[5]Taken from following website: http://salary.com/.
[6]Fringe benefits estimated to be 30% of Total Salaries.
[7]Incidental expenses estimated to be 28% of Salaries and Manager/Employee benefits.
[8]Based on Berwick (2007) with adjustments made for equipment complement and time period.
[9]Calculated to be 5% of total investment and equipment. Based on Berwick (2007), with adjustments for location, time period, and equipment complement.

REFERENCES

Andrieu, N. and L. Weiss (2008). *Transport Mode and Network Architecture: Carbon Footprint as a New Decision Metric.* Thesis submitted to Engineering Systems Division in partial fulfillment of a Master of Engineering in Logistics at the Massachusetts Institute of Technology. Accessed September 12, 2010. http://dspace.mit.edu/handle/1721.1/45250

Babcock, M. W., J. L. Bunch, J. Sanderson, and J. Witt (2003a). *Economic Impacts of Railroad Abandonment on Rural Kansas Communities.* Kansas Department of Transportation, Report No. KS-03-4. Topeka, Kansas.

Babcock, M.W., J. L. Bunch, J. Sanderson, and Witt (2003b). Impact of Short Line Railroad Abandonment on Highway Damage Costs: A Kansas Case Study. *Journal of the Transportation Research Forum,* 57 (4) (2003):105-121.

Berwick, M. (2007). *Feasibility of a Logistics Center Including Container/Trailer Intermodal Transportation in Fargo/Morehead.* Upper Great Plains Transportation Institute, Report DP-193, North Dakota State University. Fargo, North Dakota. September 2007. Accessed June 18, 2010. http://www.ugpti.org/pubs/pdf/DP193.pdf

Bitzan, J. and D. Tolliver (2001). *North Dakota Strategic Freight Analysis. Item IV. Heavier Loading Rail Cars.* The Mountain-Plains Consortium : A program of Upper Great Plains Transportation Institute, MPC Report 01-127.4, North Dakota State University, Fargo, North Dakota.

Cotton Board (2009). *Gin Code List*. Accessed May 18, 2010. http://www.cottonboard.org/CB_Home.aspx?SectionID=4&ContentURL=CBBuyer1\gincodelist.htm&TabID=2&ContentType=2&ContentURLID=29

Environmental Protection Agency (EPA) (2010). *MOVES Motor Vehicle Emissions Simulator,* Office of Transportation and Air Quality. Accessed August 12, 2010. http://www.epa.gov/otaq/models/moves/index.htm

EPA SmartWay Transport (2006). *Savings Calculator*. Accessed September 19, 2010. http://www.epa.gov/smartwaylogistics/transport/calculators/index.htm

Fellin, L., S. Fuller, J. Kruse, S. Meyers and A. Womack (2008). "The Upper Mississippi and Illinois Rivers as Grain Transport Arteries; A Spatial Equilibrium Analysis," *Journal of the Transportation Research Forum.*47 (2) (2008):73-88

Franzese, O., H. E. Knee, and L. Slezak (2009). *Effect of Tires on Class-8 Heavy Truck Fuel Efficiency.* Accessed March 23, 2010. http://info.ornl.gov/sites/publications/files/Pub20686.pdf

Fuller, S., P. Randolph, and D. Klingman (1976). "Optimizing Subindustry Marketing Organizations: A Network Analysis Approach." *American Journal of Agricultural Economics,* 58, (2), (1976):131-14.

Intercontinental Exchange (ICE) (2009), *Cotton Certified Stock Report.* Accessed May 8 2010. https://www.theice.com/marketdata/nybotreports/getCottonWarehouseReportsResults.do;jsessionid=F818A4B4255B809287140AD74AF1CEC5

INRIX (2009). *National Traffic Scorecard*. Accessed February 12, 2010. http://www.usatoday.com/news/nation/2010-02-22-inside-congestion_N.htm#table

Lubbock Economic Development Alliance (2009). Property Values. Accessed March 15, 2010 http://www.lubbockeda.org/ (Accessed March 15, 2010).

Manta (2009a). *Broadwoven Fabric Mills, Companies in the US.* Accessed on May 16, 2010. http://www.manta.com/mb_34_E90D3_000/broadwoven_fabric_mills_cotton

Manta (2009b). *Cotton Spinning Mills in the U.S*. Accessed on May 16, 2010 http://www.manta.com/mb_34_E9119_000/yarn_spinning_mills

McKinnon, A. (2007). *CO_2 Emissions from Freight Transport in the UK*. Report prepared for the Climate Change Working Group of the Commission for Integrated Transport. Logistics Research Center, Heriot-Watt University, Edinburgh, Scotland. Accessed July 21, 2010. http://resilientcities.gaiaspace.org/mushin/files/-1/7/2007climatechange-freight.pdf

Michigan Department of Transportation in cooperation with U.S. Department of Transportation (2008). *Detroit Intermodal Freight Terminal: Wayne and Oakland Counties, Cost Estimates*, August, 2008.

Minnesota Department of Agriculture and Wilbur Smith Associates (2008). *Accessing Feasibility of Intermodal Transport of Agricultural and Related Products on Short Line and Regional Railroads.* Minnesota Department of Agriculture. Accessed on June 8, 2010. http://www.mda.state.mn.us/news/publications/food/business&marketing/intermodaltrans.pdf

Stewart, R.,L. Ogard and F. Harder (2004). Intermodal Terminal Requirements for Small to Medium Size Communities: A Case Study, Transportation Research Board, 83rd Annual Meeting, Washington, DC, January 2004

Surface Transportation Board (STB) (2008). *Public Use Waybill*. Accessed May 24, 2010. http://www.stb.dot.gov/stb/industry/econ_waybill.html

Texas Cotton Association (2009). *Texas Warehouse Tariffs.* Accessed April 22, 2010. http://www.storesonline.com/site/417921/page/428041

Texas Department of Transportation (2008). *100 Most Congested Roadway Segments in Texas.* Accessed June 23, 2010. http://apps.dot.state.tx.us/apps/rider56/list.htm

Tol, R.S. (2005). "The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of Uncertainties." *Energy Policy*. 33 (16) (November 2005):2064-2074.

Tolliver, D., and HDR Engineering INC. (2000). *Benefits of Rail Freight Transportation in Washington: A Multimodal Analysis*. Appendix D, Washington State Department of Transportation, Olympia, Washington.

Transportation Research Board (TRB) (2007). *Rail Freight Solutions to Roadway Congestion—Final Report and Guidebook.* National Cooperative Highway Research Program, Report 586, Washington. DC.

Transportation Research Board (TRB) (2009). *Public and Private Sector Interdependence in Freight Transportation Markets.* National Cooperative Highway Research Program, Report 1, Washington. D.C.

Transportation Research Board (TRB) (2010). *Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.* Committee to Assess Fuel Economy Technologies for Medium and Heavy-Duty Vehicles, Board on Energy and Environmental Systems, National Research Council of National Academies. The National Academies Press, Washington, D.C.

Upper Great Plains Transportation Institute (2007). *Feasibility of a Logistics Center including Container/Trailer Intermodal Transportation in the Fargo/Moorhead Area.* North Dakota State University, September 2007.

U.S. Census Bureau (2009a). Current Industrial Reports. *M313P-Consumption on Cotton System and Stocks, Table 2. Consumption and Stocks, End of Period, Held by Consuming Establishments of Cotton, Manmade Fiber Staple, and Linters.* Accessed on May 14, 2010. http://www.census.gov/manufacturing/cir/historical_data/m313p/index.html

U.S. Census Bureau (2009b). Current Industrial Reports. *M313P-Consumption on Cotton System and Stocks, Table 2A. Stocks, End of Period, of Cotton Held in Public Storage and at Compresses.* Accessed on May 14, 2010. http://www.census.gov/manufacturing/cir/historical_data/m313p/index.html

U.S. Department of Agriculture (USDA) (2009a). Agricultural Marketing Service. *USDA-AMS Cotton Program, National Database*. Accessed on May 22, 2010. http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELDEV3018864

U.S. Department of Agriculture (USDA) (2009b). Economic Research Service. *Cotton and Wool Yearbook 2009*. Accessed on May 10, 2010. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do;jsessionid=CE671F92DEE07AA53FA28AF7EE31EA07?documentID=1282

U.S. Department of Agriculture (USDA) (2009c). Farm Service Agency. *Cotton On-line Processing System*. Accessed on June 12, 2010. https://dlnt01.fsa.usda.gov/logon.jsp

U.S. Department of Agriculture (USDA) (2009d). National Agricultural Statistical Service. *Quick Stats 1.0*. Accessed on May 23, 2010. http://www.nass.usda.gov/U.S.

U.S. Department of Agriculture (USDA) (2010). Office of the Chief Economist. Accessed on May 18, 2010. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1282

U.S. Department of Energy (DOE)(2009). U.S. Energy Information Administration. *Monthly On-Highway Retail Diesel Prices.* Accessed on May 18, 2010. http://tonto.eia.doe.gov/oog/info/wohdp/diesel.asp

U.S. Department of Transportation (USDOT) (1997). Federal Highway Administration. *Federal Highway Cost Allocation Study: Summary Report.* http://www.fhwa.dot.gov/policy/hcas/summary/index.htm

U.S. Department of Transportation (USDOT) (2000). Federal Highway Administration, *FHWA Functional Classification Guidelines.* Accessed on August 10, 2010. http://www.fhwa.dot.gov/planning/fctoc.htm

U.S. Department of Transportation (USDOT) (2000a). Federal Highway Administration. The *Comprehensive Truck Size and Weight Study*, FHWA-PL-00-029 (Volume I Summary Report). http://www.fhwa.dot.gov/policy/otps/truck/index.htm

U.S. Department of Transportation (USDOT) (2000b). Federal Highway Administration. *The Comprehensive Truck Size and Weight Study*, FHWA-PL-00-029 (Volume II Issues and Background). http://www.fhwa.dot.gov/reports/tswstudy/Vol2-Chapter6.pdf

U.S. Department of Transportation (USDOT) (2006). Federal Highway Administration, *Price Trends for Federal-Aid Highway Construction.* http://www.fhwa.dot.gov/programadmin/pt2006q1.cfm

U.S. Department of Transportation (USDOT) (2010). Federal Highway Administration. *Construction Cost Trends for Highways, Table PT-1*, Accessed on August 10, 2010 http://www.fhwa.dot.gov/ohim/nhcci/pt1.cfm

Vachal, K., and M. Berwick (2008). *Exporting Local Grains Via Container from an Illinois River Agricultural Hub.* Accessed on June14, 2010. http://www.ilsoy.org/_data/mediaCenter/files/608.pdf

Victoria Transport Policy Institute (2008). *Parking and Loading Space Minimum Requirements, Table.5.1-6(f)*. http://www.city of vernon.org/assets/docs/Park Regs.pdf.

Warner, J., and M.S. Terra (2006). *Assessment of Texas Short Line Railroads*. Transportation Research Board, 85th Annual Meeting, Washington, D.C. http://ctr.ra.utk.edu/LRRFT/cmte_activities/papers/TRBAM%2006-WarnerTerra.pdf

Washington State Department of Transportation (2003). *East Washington Grain-Hauling Short-Line Rails.* Study carried out by HDR Engineering Inc. and Denver Tolliver. February 2003. http://www.palouse.org/rtpo/PRT PappendixCgrainhaultin_rpt.pdf

Wilson, W.,B.L. Dahl, R. Taylor and W. Koo (2007). *Grain Shipments on the Mississippi River System: A Long-term Projection*. Center for Agricultural Policy and Trade Studies, Department of Agricultural Economics, North Dakota State University, July 2007. http://ageconsearch.umn.edu/bitstream/9080/1/aer605.pdf

WISERtrade (2009). *Foreign Trade Data*. Accessed on March 18, 2010. h http://www.wisertrade.org/home/index.jsp

World Resources Institute (WRI) and World Business Council for Sustainable Development (WBCSD) (2003). *The Greenhouse Gas Protocol Initiative.* Accessed on July 22, 2010. http://www.ghgprotocol.org/calculation-tools