Impact of Global Recession in Containerized Agricultural Shipments: A Case Study of Texas Cotton

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ABSTRACT

This paper builds on previous work investigating least cost shipment and storage of cotton from Texas, the largest U.S. producer of cotton. The model is used to analyze the effects of reduced export demand on shipping patterns and costs to the overall cotton transportation system. In addition, we apply road deterioration parameters from the literature to derive rough estimates of impacts of public roads.

INTRODUCTION

Robinson et al. (2007) previously documented major forces influencing U.S. cotton transportation and logistics. Formerly, U.S. cotton production was mainly trucked or railed to southeastern domestic mills. A major shift towards globalized fiber and textile markets in the 1990s saw the demise of the U.S. cotton milling industry, the concurrent development of an export-based cotton marketing system, and the dominance of Far East imports and textile production. U.S. cotton exports increased from 3 million bales in 1999 to about 15 million bales by 2005. Today approximately two-thirds of U.S. cotton production is exported, almost all of it using marine containers.

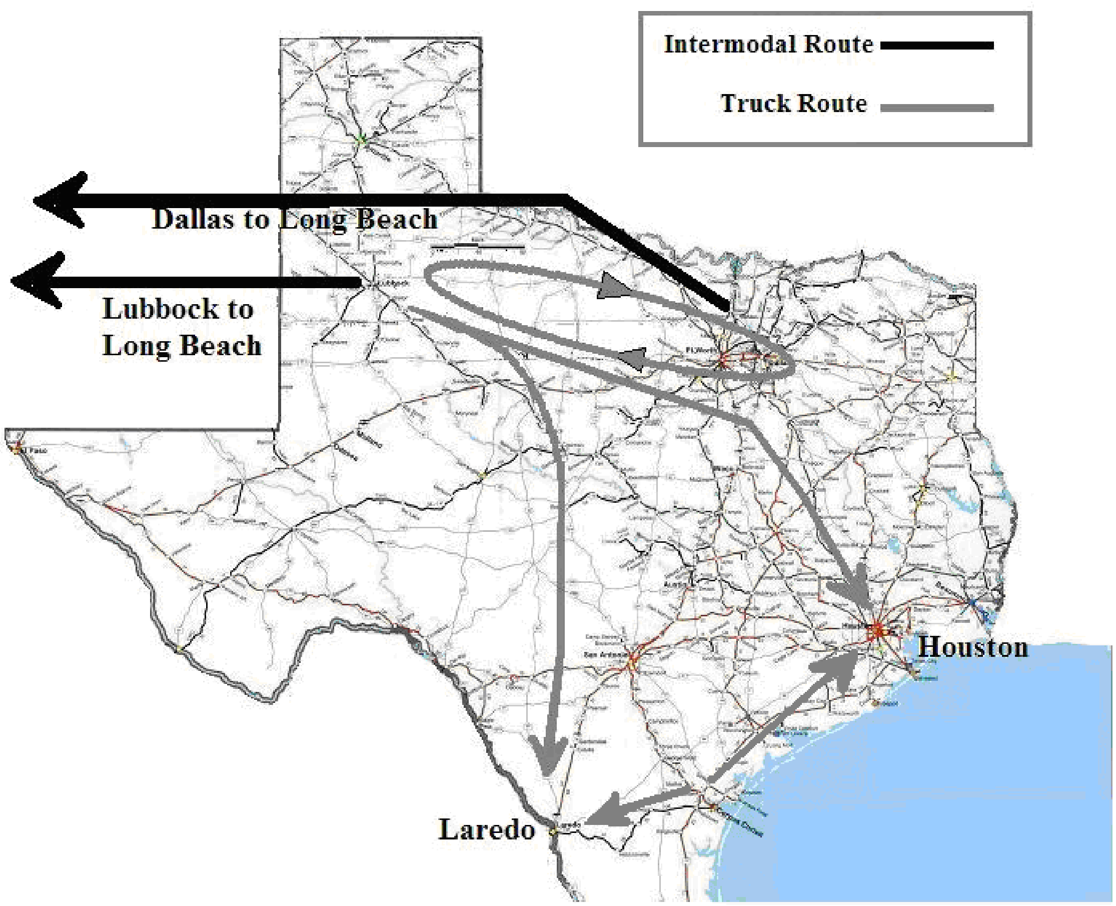
Despite global shifts in textile production, the U.S. remains the third largest supplier of raw cotton fiber in the world with between 13 and 20 million bales produced annually. The state of Texas has historically accounted for about a third of U.S. cotton production (Robinson and McCorkle, 2006), and this production share appears to be increasing to over half (USDA NASS, 2008).

Because of underdeveloped intermodal linkages in the rural production areas of Texas, circuitous routings of cotton occur with potentially unnecessary traffic placed on rural and interstate connectors that link to intermodal facilities in congested metro centers (Dallas, Houston), congested Mexican border crossings (Laredo), and west coast ports (Long Beach/ Los Angeles). It is feasible, albeit expensive, to truck cotton from the Texas High Plains to transshipment locations and/or ports like Dallas (ca. 300 miles), Houston (ca. 500 miles), or Laredo (ca. 500 miles) (Figure 1). Similarly, cotton produced on the gulf coast is trucked to port at either Houston or the Mexican border. The Texas High Plains region has rail access through the Burlington Northern Santa Fe (BNSF). The BNSF provides the only direct link to west coast ports via a Lubbock intermodal facility. This facility has been operated by one private cotton merchandising firm, with a capacity to ship twenty to twenty five percent of the region's production. The BNSF also serves intermodal facilities in the Dallas/Fort Worth and Houston areas. The only alternative rail carrier is the Union Pacific (UP) from intermodal facilities located near Dallas and Houston. Thus, a large majority of the region's cotton production requires substantial trucking. For example, the Texas High Plain's inadequate capacity to accommodate intermodal traffic requires that empty containers and chassis be trucked from Dallas for loading and subsequent return to access the intermodal network around Dallas/Fort Worth (Figure 1). Further, rail shipment of the region's Asian-bound shipments is dependent on only two long haul rail carriers. Oligopolistic rail rates may thus be an issue (Fraire et al., 2008).

The shift of the U.S. cotton industry towards exports has imposed structural shifts on to regional shipping systems. It has also exposed those systems to more risk, e.g., shifts in export demand. While the last ten years have seen variations in demand from major importers like China, the unfolding recession of 2008 has affected many commodity markets. Cotton demand appears to be hurt worse by economic recession than other agricultural commodities as cotton is an industrial input into the manufacture of relatively discretionary consumer products like clothing and home furnishings. While it is still too early to assess the impacts of the broad market declines in 2008, USDA has lowered forecasted export demand for U.S. cotton from over 16 million bales to below 13 million (USDA NASS, 2008). More than half of this decline reflects a reduction in forecasted demand from the Far East.

The decline in export demand has local implications for Texas cotton traffic. The Texas cotton industry had been exploring an expansion of intermodal capacity linking the Texas High Plains with the West Coast. However, the recent collapse of global cotton trade has apparently halted these plans. Indeed, the fears are now for the continuing feasibility of the existing Lubbock, TX intermodal facility due to reduced volume. The purpose of this paper is to examine the impacts of decreased shipments from this facility, in addition to a broad look at decreased export demand. We extend previous research in this area by: 1) modeling cotton flows for the entire State of Texas, 2) sourcing cotton at the gin level, and 3) examining public cost impacts beyond the cotton transportation system.

Figure 1. Truck and Intermodal Routes for Texas Cotton.



METHODS

Model Formulation

Anecdotal evidence from interviews with cotton shipping industry representatives confirm that cotton shipments tend to “flow like water”, i.e., they follow a least cost pattern. Therefore a cost minimizing mathematical programming model was developed to represent the Texas cotton transportation and logistic system in considerable detail. A description of the basic model in summation notation follows.

(1) Objective function:

$$\textbf{Min} \sum_{G}\sum_{W}\sum_{Q} c_{GW} X_{GWQ} + \sum_{W}\sum_{P}\sum_{Q} c_{WP} X_{WPQ} + \sum_{W}\sum_{I}\sum_{Q} c_{WI} X_{WIQ} +$$

$$\sum_{W}\sum_{M}\sum_{Q} c_{WM} X_{WMQ} + \sum_{W}\sum_{P}\sum_{Q} c_{WP} X_{WPQ} + \sum_{I}\sum_{P}\sum_{Q} c_{IP} X_{IPQ} + \sum_{W}\sum_{Q\text{-}Q4} cs_{WQ} H_{WQ}$$

(2) Quarterly Gin Supply Endowment/Shipment Equation:

$$\sum_{W} X_{GWQ} = S_{GQ}$$

(3a) Quarterly Minimum Demand Constraints for Ports:

$$\sum_{W} X_{WPQ} + \sum_{I} X_{IPQ} \geq D_{PQ}$$

(3b) Quarterly Minimum Demand Constraints for Mills:

$$\sum_{W} X_{WMQ} \geq D_{MQ}$$

(4) Quarterly Warehouse Shipment Balance Constraints:

$$\sum_{P} X_{WPQ} + \sum_{M} X_{WMQ} + \sum_{I} X_{WIQ} + ST_{WQ} \leq ST_{WQ-1} + \sum_{G} X_{GWQ}$$

(5) Quarterly Intermodal Point Shipment Balance Constraints:

$$\sum_{P} X_{IPQ} \leq \sum_{W} X_{WIQ}$$

(6) Warehouse Capacity Constraint

$$ST_{WQ} \leq Capacity_{W}$$

(7) Lubbock Intermodal Capacity Constraint

$$\sum_{P}\sum_{Q} X_{\text{"Lubbock"}PQ} \leq 1{,}000{,}000$$

(8) Nonnegativity Constraint:

$$X\ ,\ ST \geq 0$$

Equation (1) minimizes the sum of costs (*C*) of shipping (*X*) and storage (*ST*) activities of cotton bales originating in (G=249) gins and flowing to (W=83) warehouses operating across Texas over four three month quarterly periods. Q1 corresponds to the August-October quarter which marks the beginning of the cotton marketing year. The model allows for routing cotton shipments from originating gins to warehouses, and then to either (p=2) Texas ports of exit, (m=2) domestic mills, or (i=3) intermodal facilities (and thence by rail to the port of Los Angeles/Long Beach. Lastly, quarterly storage in warehouses is allowed, with fourth quarter storage representing carryover into the next marketing year.

Equation (2) supplies cotton gins with quarterly endowment of cotton, which they must then ship to warehouses within that same quarter.

Equations (3) are demand constraint requiring the shipment of minimum quarterly amounts to the final demand points (ports, P, and mills, *M*). Relevant ports include Galveston/Houston, Laredo, Los Angeles/Long Beach, while relevant mills include a Littlefield, TX denim mill, and Gadsden, AL (a proxy location for southeastern U.S. mills).

Equations (4) constrain the sum of quarterly shipments from warehouses to intermodal facilities (*I*), ports (P), or mills (*M*) plus present quarter storage (ST_Q) to be no more than incoming new crop shipments from gins plus previous storage (ST_{Q-1}). Similarly, equation (5) constrains quarterly shipments from intermodal facilities from exceeding the sum of their incoming quarterly shipments from warehouses.

Equation (6) constrains the quarterly storage in warehouses from exceeding their official capacity. Equation (7) constrains shipments from the Lubbock intermodal site to Los Angeles/Long Beach to no more than 1,000,000 bales. Equation (8) is the standard non-negativity constraint in linear programming.

Data Development

Gin information. The location and capacity of cotton gins was obtained through primary and secondary sources. We used the Cotton Board’s (2008) list of gins to identify gins by county/city. This list includes about 95% of all existing gins. In addition, we used information from a gin database maintained by Dr. Calvin Parnell (2008) to identify and locate remaining gins, as well as quantify their capacity. This information was used to develop a phone survey process that was implemented during Fall 2008 (Tieman et al., 2008). We telephoned the entire list of Texas cotton gins with a set of questions focusing on 1) which warehouses they primarily shipped to, 2) their current trucking costs, 3) any subsidies or rebates from warehouses, and 4) information about their expected ginning volume.

Warehouse information. The location and capacity of warehouses was obtained from the Commodity Credit Corporation list of approved cotton warehouses (USDA-AMS, 2007). Individual warehouse tariff data (i.e., receiving, loading, and storage costs) were obtained from primary (Robinson et al., 2007) and secondary sources (Lubbock Cotton Exchange, 2007).

Supply specification. 2008 forecasted cotton production data for Texas NASS districts were collected from USDA NASS (2008). Forecasted production was used as an expected value instead of a five year average because of the recent major decline in cotton acreage. Forecasted production, by NASS district, was allocated to gins within that district proportionately by gin capacity. The cotton harvest in Texas is typically spread over several months between August and February. We allocated the expected supply to each gin over three quarters, based on the quarterly proportion of bales classed at the USDA-AMS Texas classing offices for 2003-2007 (USDA AMS, 2007). For example, in West Texas about 10% of expected new crop supplies are typically allocated during the August-through-October quarter, 80% allocated during November-January, and 10% allocated in February-March. South and Central Texas supplies are allocated mostly during the August-through-October quarter.

Demand specification. Cotton export data is generally only available at the aggregate, national level, e.g., U.S. weekly exports to specific destinations (USDA FAS, 2007). We used secondary export data compiled by WISERTrade (2006) to estimate average (over 2003 through 2005) quantities of cotton crossings by port of exit. We crossed checked these data with reported shipments by surveyed Texas warehouses (Robinson et al., 2007) to known destinations to derive minimum quantities of Texas cotton demanded at ports or domestic mills.

Distance matrices. Road mileage between originating gins, warehouses, intermodal facilities, ports, and mill locations were calculated using available online mapping software (e.g., www.mapquest.com). The relevant ports were Houston-Galveston, Laredo (representing the entire South Texas border), and Los Angeles/Long Beach. The relevant mills were Littlefield, TX and Gadsden, AL (the latter reflecting a representative westerly destination for the small amount of Texas cotton that is trucked to the Southeast). Railroad mileages between intermodal facilities and the Port of Long Beach were obtained from the BNSF and UP websites.

Transportation rates. Truck mileage costs associated with the distance matrix were developed based on recent phone survey data collected from Texas gins. The data were used to estimate a univariate regression of trucking cost as a function of mileage. The resulting regression parameters were used to derive point estimates of trucking costs for the specific distance matrix elements for all gin-warehouse, warehouse-intermodal, warehouse-port, and warehouse-mill combinations.
Shipping costs from intermodal points to ports were calculated using rail mileage times average waybill railroad rates. Unfortunately, there is very little information available on railroad rates for shipping cotton. The merchants and freight forwarders have little experience with separate railroad rates as they negotiate rates on warehouse to Asian mill basis, i.e., combined truck, intermodal, and steamship through rates. The publicly available waybill data sample for 2003-2006 has 556 observations of intermodal shipment from Lubbock to Long Beach. From these data we calculated an average rate

of $8.86/bale, along with a large standard deviation. The latter could suggest either seasonal effects on prices or differential (i.e., oligopoly) pricing of this Lubbock-Long Beach route. Other intermodal rates (DFW-Long Beach, and Houston-Long Beach) were set based on anecdotal evidence from industry.

RESULTS AND DISCUSSION

Section 1: Baseline and Reduced Export Demand Scenarios.

Balancing supply/demand. The model defined by Equations (1) through (7) was compiled and solved using GAMS. The basic model results exhibited expected least cost behavior similar to that described by Fraire et al (2008). For example, truck shipments to mills or ports tended to be sourced from cotton warehouses relatively close by. For example, shipments to the ports of Laredo or Galveston/Houston were sourced from Central and South Texas warehouses. Similarly, as found by Fraire et al. (2008), truck shipments to the Dallas/Ft. Worth intermodal site tended to be sourced from easterly regions of West Texas (i.e., the Rolling Plains region) while warehouses around Lubbock were sources of shipments to the Lubbock intermodal site. As in the Fraire et al. study, the model maximized the available intermodal shipments from Lubbock to Los Angeles/Long Beach (constrained at 1,000,000 bales annually) due to the relative cost efficiency. Fourth quarter carryover storage in this model was located in relatively remote warehouse location. Aggregate shipments (across all warehouses and all four quarters) and fourth quarter storage for the baseline scenario are shown in the “100%” headed column of Table 1.

Reduced Export Demand. Table 1 shows the effects of across-the-board percentage reductions in demand at the ports of Galveston/Houston, Laredo, and Los Angeles/Long Beach. These reductions are in keeping with an assumed reduction in U.S. exports due to recession. In general, greater percent reductions in export demand resulted in rather predictable declines in shipments from warehouses to ports and intermodal sites, and increases in fourth quarter carryover storage (Table 1). However, the decreased cotton flow from warehouses was not proportionately even. The decreases in intermodal shipments to Los Angeles/Long Beach were borne by the Dallas/Ft. Worth intermodal site (again, because of the relatively cost efficiency of the Lubbock intermodal site). Therefore, relative to the baseline, the flows of cotton from warehouses (not shown) were least reduced from those warehouses in the vicinity of Lubbock that supply that intermodal site. Flows from warehouses positioned to supply Dallas/Ft. Worth saw reduced shipments and greater fourth quarter carryover storage, relative to the baseline, under the reduced demand scenario. However, as the level of demand reduction approached 50%, the number of West Texas warehouses with fourth quarter carryover storage in West Texas warehouses increased three-fold (not shown) to accommodate the required storage.

Table 1. Least Cost Cotton Bale Shipments with Baseline (100%) Port Demand and Across-The-Board Reductions in Port Demand from 90% to 50%.

A. Annual Bale Shipments Across All Warehouses to Ports, by Port and Port Demand Level.						
	100%	*90.0%*	*80.0%*	*70.0%*	*60.0%*	*50.0%*
Galveston/Houston	1,028,548	925,693	822,838	719,984	617,129	514,274
Laredo	490,599	441,539	392,479	343,419	294,359	245,300
B. Annual Bale Shipments Across All Warehouses to Intermodal Sites, by Site and Port Demand.						
	100%	*90.0%*	*80.0%*	*70.0%*	*60.0%*	*50.0%*
Dallas/Ft. Worth	2,614,504	1,270,930	1,018,605	766,279	513,954	261,628
Lubbock	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
C. Annual Bale Shipments From Intermodal Sites to LA/LB, by Port Demand.						
	100%	*90.0%*	*80.0%*	*70.0%*	*60.0%*	*50.0%*
Dallas/Ft. Worth	1,523,256	1,270,930	1,018,605	766,279	513,954	261,628
Lubbock	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
D. Fourth Quarter Carryover Storage of Bales Across All Warehouses, by Port Demand Level.						
	100%	*90.0%*	*80.0%*	*70.0%*	*60.0%*	*50.0%*
	790,185	1,172,680	1,574,642	1,740,048	2,042,981	2,229,275

In summary, an across-the-board reduction in export demand produced reasonable results in terms of reduced upstream flows from warehouses to ports and intermodal facilities. Fourth quarter carryover storage increases with the reduction in export demand, as would be expected (and has been seen in years of oversupply or demand contraction). Lastly, the model responded to reduced export demand by shifting flows to meet a new least cost situation.

While shifts in supply and demand may endure for a year or two, the effects on fixed shipping/handling infrastructure can be more lasting. The remainder of this paper focuses on the impacts on a site of particular importance: the relatively cost efficient intermodal origin site at Lubbock, TX. While this facility is a cheaper alternative for shipping containers to the West Coast (relative to Dallas/Ft. Worth), it faces challenges from its limited capacity, rural location, and access to supplies of shipping containers. These challenges have been the major obstacles in plans for expanded intermodal capacity at Lubbock. With the current reduction in export demand (circa Fall 2008) the continued feasibility of operating the existing Lubbock facility is a concern within the Texas cotton industry. The following section focuses on a sensitivity of reduced capacity at the existing Lubbock facility, calculating increased costs to the cotton transportation system as well as to the public.

Section 2: Sensitivity of Reduced Lubbock Intermodal Capacity.

Using baseline export demand levels, the model was solved at various levels of available capacity for the current Lubbock intermodal facility (Table 2). This sensitivity analysis of reduced intermodal capacity could reflect the unavailability of shipping containers, and/or the lack contractual agreements between the BNSF and cotton merchandizing firms due to export uncertainties.

Table 2. Sensitivity Analysis of Baseline Intermodal Capacity for Lubbock, TX: Overall Shipping/Handling System Costs, and Related Truck Miles from Warehouses To Dallas/Ft. Worth and Lubbock Intermodal Sites.

LUBBOCK CAPACITY	PERCENT BASELINE S&H COST	DFW ROUTE TRUCKMILES	LUBBOCK Rt. TRUCKMILES
1,000,000	100%	5,229,802	478,751
900,000	102%	5,594,348	423,296
800,000	104%	5,958,986	367,749
700,000	106%	6,323,107	315,144
600,000	107%	6,690,402	266,322
500,000	109%	7,058,811	212,913
400,000	111%	7,439,976	161,724
300,000	113%	7,822,817	117,406
200,000	116%	8,208,104	78,891
100,000	118%	8,593,786	44,119

Table 2 shows the increased shipping and handling costs to the cotton transportation system resulting from reduced intermodal capacity at Lubbock. The Lubbock site is relatively cost efficient due to its westerly location (relative to Los Angeles/Long Beach) and its proximity to large warehouse supplies of cotton. Any reductions in available Lubbock intermodal capacity implies that more cotton must be routed by truck back to Dallas/Ft. Worth (Figure 1) which increases trucking costs and truck miles. The latter can be clearly seen in the third and fourth columns. For example, with the baseline Lubbock intermodal capacity of 1,000,000 million bales per year, the truck miles to Dallas/Ft. Worth are minimized at 5.2 million (i.e., these are the highway miles covered by an assumed flatbed truck with 88 bales of 500 lbs each, from West Texas warehouses along regional highways and ultimately Interstate 20 east to Dallas/Ft. Worth (Figure 1)). Likewise, the truck miles from nearby West Texas warehouses along rural and regional highways to Lubbock are maximized at 478,751 miles. As the Lubbock intermodal capacity is reduced below 1,000,000 bales, the truck miles to Dallas/Ft. Worth increase, those to Lubbock decrease, and the system shipping and handling costs rise (Table 2).

Thus, while the Lubbock intermodal facility presents a challenge to operate (i.e., in supplying it with steady volumes of containers and cotton) it is clearly of major economic importance to the Texas cotton transportation and marketing system. In an attempt to garner additional support for maintaining this facility, others have previously considered the external benefits of reduced truck miles on Texas highways afforded by the Lubbock intermodal facility. The final section attempts to quantify the additional cost to the State of Texas, in terms of pavement degradation, of the range of traffic flows evaluated in Table 2. As this is a complex area of study, we review two strands of literature for guidance on pavement cost estimates. The first line of literature draws from studies on the abandonment of shortline railroads and the consequential impact on incremental truck miles released on roadways and pavement deterioration. The second line of literature draws on studies like employ per-truck mile estimates that provide guidance on pavement costs on a per truck mile basis. Together these studies indicate that pavement costs of closing down an intermodal facility or the addition of one could have significant pavement related impacts and other economic impacts.

Pavement Damage Cost Equivalent Single Axle (ESAL) Based Studies

Babcock et al. (2003a, 2003b) conducted a study to estimate road damage costs caused by increased truck traffic resulting from the proposed abandonment of shortline railroads serving western and central Kansas. The study area included the western two-thirds of the state. Their objective was achieved in a three-step approach. First, a transportation cost model was developed to compute how many wheat car loadings occurred at each station on each of the four-shortline railroads in the study area. Then, the shortline railroad car loadings at each station were converted to truckloads at a ratio of one rail carload equal to four truck loads. Finally, a 4-step pavement damage model presented by Tolliver (2000) was employed to calculate the additional damage costs for county and state roads attributed to the increased grain trucking due to shortline abandonment. The study also used a time decay model and an equivalent-single-axle model to examine how increased truck traffic affected pavement service life. Pavement data inputs required by the models used in the study included designation as U.S., Kansas, or Interstate highway, transportation route number, beginning and ending points of highway segments by street, mile marker, or other landmarks, length of pavement segment, soil support values, pavement structural numbers, annual 18-kip traffic loads, and remaining 18-kip traffic loads until substantial maintenance or reconstruction. These data were obtained from the Kansas Department of Transportation CANSYS database. The road damage cost resulting from abandonment of the short line railroads in the study area could be divided into two parts: 1) costs associated with truck transportation of wheat from farms to county elevators; and 2) costs of truck transportation of wheat from county elevators to shuttle train stations and terminal elevators. The study found that the shortline railroad system in the study area annually saved $57.8 million in road damage costs. The annual damage cost for Kansas shortline railroads ranged from a minimum of $4.13 per truck mile to a high of $8.08 per truck mile for a total of $7.17 combined cost per truck mile. In addition, the abandonment related loss in truck user fees were obtained at the Kansas 25c per gallon fuel tax rate and using the 7 mpg fuel efficiency parameter leading to $288,531 which was very low when compared to the gain of $57.8 million in damage costs.

In eastern Washington, grain shippers were utilizing the Lower Snake River for inexpensive grain transportation. However, the truck-barge grain transportation with longer distances resulted in higher damage costs for the principal highways in this geographical area. Lenzi et al. (1996) conducted a study to estimate the deduction of the state and county road damage costs in Washington by proposing a drawdown usage of the Lower Snake River. The researchers proposed two potential drawdown scenarios. Scenario I assumed that the duration of drawdown was from April 15 to June 15; and scenario II assumed that the duration of the drawdown was from April 15 to August 15. During the drawdown, trucking would be the only assumed shipping mode to the nearest elevators with rail service. Since the average length of haul for a truck to an elevator was estimated as 15 miles compared with 45 miles for truck barge movements, the shifting from truck-barge mode to truck-rail mode would result in less truck miles traveled and thus would cause a significant reduction of highway damage. Based on a series of assumptions suggested by similar studies, the total road damage costs before the Lower Snake River drawdown was estimated as $1,257,080 for Scenario I. The road damage cost after Scenario I drawdown was calculated in a similar manner at $459,770, or 63% less than the pre-drawdown cost. For scenario II, the drawdown was estimated to be able to reduce road damage costs by $1,225,540, or 63% than the pre-drawdown costs which was estimated as $3,352,240. The researchers concluded that with adequate rail car supply, both drawdown scenarios would decrease the system-wide highway damage costs, although certain roadways might experience accelerated damages.

Russell et al. (1995, 1996) conducted a study to estimate potential road damage costs resulting from the hypothetical abandonment of 800 miles of railroad branch line in south central and western Kansas. First, the researchers adopted a wheat logistics network model developed by Chow (1985) to measure truck and rail shipment changes in grain transportation due to railroad abandonment. The model contained 400 simulated farms in the study area. The objective function of this model was to minimize the total transport cost of moving Kansas wheat from the simulated farms to county elevators, then from county elevators to Kansas railroad terminals, and then from railroad terminals to export terminals in Houston, TX. The model was employed for both the base case (truck and railroad wheat movements assuming no abandonment of branch lines) and the study case (after the abandonment of branch lines). Second, the researchers measured the pavement life of each highway segment in ESALs using Highway Performance Monitoring System

(HPMS) pavement functions. Finally, they estimated road damage in ESALs for each type of truck by using the AASHTO traffic equivalency functions. Results indicated that annual farm to-elevator road damage costs before abandonment totaled $638,613 and these costs would increase by $273,359 after abandonment. Elevator-to-terminal road damage costs before the abandonment were $1,451,494 and would increase by $731,231 after the abandonment. Thus the total abandonment related road damage costs would add up to $1,004,590.

HDR Engineering and Tolliver (2003) evaluated the wider economic impacts and pavement associated damage costs of shortline railroad abandonment in Eastern Washington for all commodity types. It was noted that grain was a primary commodity. Using the same 4-step approach as developed in Tolliver (2000) and employed in the Kansas study by Babcock et al (2003a,2003b) the authors estimate pavement damage costs and in addition the loss in associated user fees from trucks as part of wider cost-benefit analysis comprising safety and job-related benefits. The process involved the development of a verity of pavement cost factors including the 18-kip ESAL's, structural numbers for the pavement and structural life of the pavement. The 18-kip ESALs were obtained from AASHTO based equations while Highway Performance Monitoring System Database was used to obtain other factors and yet other factors from the Washington pavement management database. Based on the average cost method which was originally developed by Federal Highway Administration(FHWA) in 1982 as part of the highway cost allocation study, the study reports cost per truck mile traveled as 13 cents for a rural interstate, 30 cents for other principal arterial, $1.16 for minor arterial ad $1.14 for major collector. These costs were not used in the study and are with reference to an 80,000 lb 5-axle truck traveling in Eastern Washington. Using the incremental approach, and the AASHTO based design equations, the study estimates annual pavement costs from incremental trips to be $4.76 million and $598,000 in user fees.

Tolliver et al. (1994) developed a method to measure road damage cost associated with the decline or loss of rail service in Washington State. Three potential scenarios were assumed in the study: 1) the system-wide loss of mainline rail services in Washington; 2) the loss of all branch line rail service in Washington; and 3) all growth in port traffic was diverted to trucks due to potential loss of railroad mainline capacity. The study used AASHTO procedures to estimate pavement deterioration rates and HPMS damage functions to measure the pavement life of highway segments in ESALs. The research objective was achieved by using the following steps: 1) defining the maximum feasible life of an impacted pavement in years, 2) determining the life of a pavement in terms of traffic by using a standard measurement of ESALs, 3) computing the loss of Present Serviceability Rating (PSR) from a time decay function for a typical design performance period, 4) calculating an average cost per ESAL, and 5) computing the avoidable road damage cost if the railroads were not abandoned. For Scenario 1, the researchers estimated that the incremental annual pavement resurfacing cost would be $65 million and the annual pavement reconstruction cost would be $219.6 million. For Scenario 2, the study found that the annual resurfacing costs would range from $17.4 to $28.5 million and the annual reconstruction cost would vary from $63.3 million to $104 million with different truck configurations. In Scenario 3, the incremental annual pavement resurfacing costs would be $63.3 million and the annual reconstruction cost would be $227.5 million.

Pavement Cost Studies Using Benchmark Cost-Per-Truck-Mile or Comparable Estimates

Warner et al (2005) conduct an assessment of short line railroads in Texas. They estimate the pavement related costs using the same numbers reported in HDR and Tolliver 2003 study drawn from FHWA cost allocation study. Assuming largely rural impacts, and 20 cents per gallon fuel taxes, and 5 mpg fuel efficiency they compute net of user fee pavement losses to equal to 5.03 cents per truck mile on a rural interstate and 22.83 cents on a rural major collector for an annual saving of $35.3 million in net pavement damage costs (net of user fees) from reduced truck traffic on roadways (7.67 cents in user revenues). The Foundation for Intermodal Research (2003) notes that approximately 20 cents can be saved in pavement related deterioration costs per truck mile due to diversion from truck to rail suggesting that intermodal units do have the potential to have a significant impact on pavement costs. Bittel (2004) examine the range of pavement costs on a per truck mile basis and report a range of $4.13 per truck mile in Nebraska, Colorado, and Kansas to a high of $8.08 in Kansas and Oklahoma with an average for all shortline railroads to be $7.15 per truck- mile. In Washington State, average estimates are as low as 10 cents per truck mile.

Jessup and Cassavant (1998) note that the net repair costs per ton-mile $.002 for interstates, $.01 for state highways and $0.04 for county roads.

FHWA Truck Size and Weight (TSW) Cost Per-Truck-Mile Estimates

The FHWA TSW provides benchmark estimates of pavement costs per truck-mile. For reference, the benchmark costs for an 80,000 lb 5-axle semi-trailer truck are reproduced below in Table 1 for both urban and rural roadway configurations. These estimates are also based on ESAL. It is quite clear that rural impacts can be significantly higher than urban impacts based on observed differential in unit costs. These numbers are much smaller than those reported in Warner et al (2005) which are approximately 12 cents for rural interstates (5.03+7.67) and much higher for major collectors (29 cents).

Table 3. Unit Pavement Cost per Truck Mile for an 80,000 lb Semi-Trailer Five Axle

Functional Classification	*Urban*	*Rural*
Interstate	4 cents	5 cents
Principal Arterial	6 cents	12 cents
Minor Arterial	10 cents	29 cents
Major Collector	22 cents	90 cents
Minor Collector	54 cents	$1.49
Locals	$1.91	$3.87

Non-Traditional Impacts beyond Pavement Costs

Sanderson and Babcock (2005) conduct an exhaustive survey of rail to truck diversion impacts on highway maintenance costs. The common factor among all of these studies is the finding that structural characteristics of roadway are a significant factor in pavement costs. In addition, the authors point out that there are wider economic impacts of diversions beyond damage costs. Such impacts like job impacts are also cited in the HDR-Tolliver (2003) study. Finally, NCHRP Report 586 (Bryan et al. (2007) also points to several wider economic impacts including congestion cost impacts associated with road-rail freight diversion.

Summary of Road Degradation Impacts

There is a preponderance of the Tolliver ESAL based approach propounded by Tolliver using the AASHTO equations for developing estimates of the potential impacts on road damage costs. ESALs are equivalent single-axle loads rated at 18,000 pounds such that all loads, both single and tandem (dual) axles, are expressed in the number of ESALs that will pass over a pavement during its design life cycle (Casavant and Lenzi, 1989). Two economic cost methods have been identified for highway damage cost analysis: marginal cost (MC) and/or average cost and incremental cost (IC). Each cost might be short run or long run in nature. Marginal cost impact analysis reflects the additional consumption of highway capacity from the addition of one more ESAL to a highway section. Incremental costs encompass relatively large traffic increases as opposed to a single ESAL analysis. For instance, a free trade agreement might cause a shift in commodity trade between countries, thus impacting the flow of goods on highways or an intermodal terminal could cause a shift in trade flows and truck diversions. Such examples would constitute an incremental class of traffic. In such instances, it appears to be appropriate to account for a sizeable flow of traffic rather than a single vehicle as a result of a free trade agreement and/or an intermodal facility.

Approach Recommended and Bounds

This review has covered abandonment studies that employ ESAL based approaches and benchmark estimates to estimating deterioration costs. The ESAL approach requires an intensive analysis and study of multiple databases. As such, a more detailed study employing these methods is indeed one of the recommended approaches for studying deterioration costs associated with intermodal facilities. In addition, it would be equally important to study the wider economic benefit stemming from such facilities like safety impacts, and congestion cost reductions. However, due to the complexity of this approach, for this paper the approach recommended is the use of benchmark cost per truck mile factors which can be multiplied by truck load miles. Based on the National Highway Planning Network, it is apparent that the intermodal facilities like the one noted in Lubbock are likely to impact truck movements and most of these impacts are likely to be felt on functional classes 1 (Rural principal arterial interstate; rural principal arterial-other 2; rural minor collector 6; rural major collector 7), hence rural benchmarks are recommended. For instance, the increment in truck-miles to Dallas Fort-Worth (DFW) due to reduced Lubbock capacity is likely to add truckmiles to IH-20, US84 with functional classifications 1 and 2 respectively.

12 cents per truck mile rate is recommended for principal arterial interstate; while other numbers can follow the TSW study. The actual analysis of costs depends on the assumed diversions to the variety of roads. This cannot be accomplished in the absence of a network analysis. However, as a first cut it would be alright to use mapquest based routes to decide how to determine cost per truck mile per roadway type. These costs per truck mile need to be netted out by 5.03 cents to reflect the loss in user fees that trucks pay. These can provide annual estimates of costs. From Table 2, in going from a 1 million capacity to 900,000, there is an increment in DFW truckmiles by 423,296 and a reduction in Lubbock truckmiles by 55,455. Using the net of user fee cost per mile figures, this could have a net impact on pavement costs to approximately $1.5 million.

This research in an attempt to provide a preliminary estimate of potential pavement related costs from intermodal facilities. Pavement costs are often found to be the most significant component of a benefit cost analysis. The approach employed relies on the use of benchmarks as a first cut approach and future research should address a more detailed analysis using an ESAL approach. In addition, a more detailed benefit cost analysis focusing on safety and other non-traditional impacts should be explored.

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