Impact of Short Line Railroad Abandonment on Highway Damage Costs: A Kansas Case Study

Structural changes have occurred in the grain logistics systems of the Great Plains states and the Canadian prairie provinces. One aspect of the structural changes has been an increase in grain trucking and a corresponding decline in short line railroad traffic. In Kansas, grain is the principal commodity market of short lines, and as more grain has been shipped by truck, short lines have lost market share in their most important market, threatening the long run viability of these railroads, which could have negative implications for rural communities.

The objective of this paper is to measure the change in Kansas state highway damage costs, resulting from assumed abandonment of short line railroads. Using Arc View Geographic Information System (GIS) software and a truck routing algorithm from Babcock and Bunch (2002), a network model was developed to route wheat through the logistics system to achieve minimum transportation costs. This analysis was performed with and without short line railroads in the wheat logistics system. The network model reveals how many wheat carloadings occur at each station on each of the short lines in the study area. Abandonment is assumed, and the short line carloadings at each station are converted to truckloads. A pavement model developed by Tolliver was used to calculate the additional damage costs for state roads attributable to the increased grain trucking following simulated short line abandonment.

Total annual road damage costs resulting from simulated abandonment was $57.8 million. Of this total, the Kansas and Oklahoma Railroad accounts for 53%; the Kyle Railroad, 27%; the Cimarron Valley Railroad, 15%; and the Nebraska, Kansas, and Colorado Railnet, 5%. The average road damage cost per truck mile for the study area was $7.15, and the average road damage cost per rail mile abandoned was $32,811. Incremental state fuel tax revenue generated by simulated abandonment was only 0.5% of annual road damage cost.

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Following passage of the Staggers Rail Act in 1980, US Class I railroads adopted a cost reduction strategy to increase profitability. Part of that strategy was the sale or lease of their rural area branchlines to short line railroads.[1] In the year 2001, Class II and III railroads operated 45,000 miles of track or 32% of the US rail system.[2] In Kansas, short lines operated 2,145 miles of track in 2002 which is about 44% of total Kansas railroad mileage.[3] Short lines play a significant role in the transportation systems of many other states as well. Thus, the economic viability of these railroads is an important issue for rural area shippers.

Railroad abandonment in Kansas has increased in recent decades. In the 1970-79 period, 415 miles of rail line were abandoned; in the 1980-89 interval an additional

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815 miles; and in the 1990-2000 period, 1,246 miles.[4] In 2001 alone, 335 miles were abandoned.[5] What has changed since 1990 is that a large proportion of abandonment is accounted for by short line railroads. In the 1990-2000 period nearly half of the 1,246 miles were abandoned by short lines.[6] In 2001, 86% of the 335 miles abandoned were accounted for by short lines.[7]

As abandonment of short lines increased, an increasing amount of Kansas grain tonnage has been diverted from short line railroad shipment to truck shipment. According to the publication *Kansas Grain Transportation* (2001), published by Kansas Agricultural Statistics, the motor carrier share of wheat shipped from Kansas grain elevators increased from 37% in 1990 to 47% in 1999. The corresponding percentages for corn shipped from Kansas grain elevators by truck were 62% in 1990 and 72% in 1999. In 1990, motor carriers accounted for 35% of the sorghum shipments which rose to 56% in 1999. For soybeans, the motor carrier market shares were 35% and 53% for 1990 and 1999, respectively.

Changes have occurred in the Kansas grain transportation system that have contributed to increased trucking of grain. Class I railroads are encouraging the construction of unit-train (100 or more railcars) loading facilities (shuttle train locations) on their main lines. Due to the scale economies of unit trains, Class I railroads offer lower prices to shuttle train shippers. In turn, this enables shuttle train shippers to pay a relatively high price for wheat. According to Rindom, Rosacker, and Wulfkuhle (1997, p. ii), Kansas farmers will truck their grain a much greater distance to obtain a higher grain price at the shuttle train location. Farmers will bypass the local grain elevator and the short line railroad serving it, and truck the grain to the shuttle train facility, resulting in increased road damage costs.

Agriculture has consolidated into fewer, larger farms. With the increased scale of operations, farmer ownership of semitractor trailer trucks has increased.[8] With these trucks, farmers can bypass the local elevator and the short line railroad serving it, and deliver grain directly to more distant markets, which will result in increased damage cost for county and state roads.

According to Babcock et al. (1993, p. 80), grain is the principal commodity of most Kansas short lines, and Babcock, Prater, and Russell (1997, p. 12) found that the most important determinant of short line railroad profitability is carloads per mile of track. Thus, increased grain trucking threatens the economic viability of short lines, possibly resulting in further abandonment of these railroads. This would cause a large diversion of grain traffic to the highways and a concomitant increase in road damage costs.

Abandonment could have negative effects on rural areas. The price paid to farmers by grain buyers is obtained by subtracting the cost of transportation from the market price. Abandonment would cause grain shippers to switch to more expensive truck transportation, and the more costly freight would result in a lower price paid to farmers for their grain. For example, if the price of wheat at export ports is \$3.30 per bushel and the transport cost to the ports is 30-cents per bushel, the net price paid to the farmer is \$3.00 per bushel (\$3.30 minus 30-cents). If the transport cost to the ports rises to 40-cents per bushel, the farmer receives only \$2.90. Of course, the loss of rail service may increase transport cost and reduce profits of other rural rail shippers as well.

In addition to higher transport costs, abandonment would result in a reduction of market options for rural shippers. Markets that are best served by rail (i.e., large volume shipments over long distances) are less available to the rural shipper after abandonment. Abandonment would result in a loss of economic development opportunities for rural communities. Firms that require railroads for inbound and/or outbound transport (i.e., shippers of food, lumber, paper, chemicals, and steel products) would not consider locating in a community that has no rail service. Since railroads are also taxpayers, abandonment would result in a loss of tax revenue needed to fund basic government services. In addition, abandonment would increase the number of trucks on the road system, possibly leading to an increase in the number of highway accidents.

Increased trucking of grain could have other negative impacts. For example, increased road congestion may produce more vehicle accidents and reduce average speeds, resulting in a rise in the opportunity cost of time in transit. The significant increase in heavy truck movements will increase the frequency and magnitude of rutting and cracking of the pavement, causing additional vehicle maintenance costs for passenger vehicle owners.

If additional motor carrier user fees are equal to the increment in truck attributable road damage costs, then other highway users and the state government are no worse off. However, Russell, Babcock, and Mauler (1995, p. 119) found that truck attributable road damage costs increase by a much greater percentage than the increase in grain transported by motor carrier. Thus, it is unlikely that additional truck user fees will cover the increase in road damage costs.

Changes in the grain logistics system discussed above are not unique to Kansas. Similar structural changes in grain transportation have been documented for Texas (Fuller et al. 2001), Iowa (Baumel et al. 1996), North Dakota (UGPTI 2001 and Machalaba 2001), and the Canadian prairie provinces (Nolan et al. 2000). Since the Great Plains states and the Canadian prairie provinces have similar grain logistics systems, the results of this paper have wide geographical scope.

Given the potential negative effects of short line railroad abandonment it is important to measure the quantifiable aspects of abandonment. The objective of this paper is to measure the change in Kansas state highway damage costs, resulting from assumed abandonment of short line railroads. To achieve this it was necessary to compute the minimum transportation cost routes for moving Kansas wheat from farms, through Kansas country grain elevators, and then through Kansas unit train loading locations to the export terminals at Houston, Texas. Using Arc View Geographic Information System software and a truck routing algorithm from Babcock and Bunch (2002), a network model is used to route wheat through the logistics system to achieve minimum total transportation costs. This analysis is performed with and without study area short line railroads in the wheat logistics system.

The network model reveals how many wheat carloadings occur at each station on each of the short line railroads in the study area. Abandonment of the short line railroads is assumed, and the short line railroad carloadings at each station are converted to truckloads at a ratio of one carload equals four truckloads. A pavement damage model published in Appendix D of *Benefits of Rail Freight Transportation in Washington*, authored by Denver Tolliver, is employed to calculate the additional damage costs for state roads attributable to the increased grain trucking following simulated short line abandonment. This study extends previous studies of the impact of railroad abandonment on road damage costs which include Casavant and Lenzi (1990), Eusebio and Rindom (1991), Tolliver, Andres, and Lindamood (1994), Russell, Babcock, and Mauler (1995), and Babcock and Bunch (2002).

THE STUDY AREA

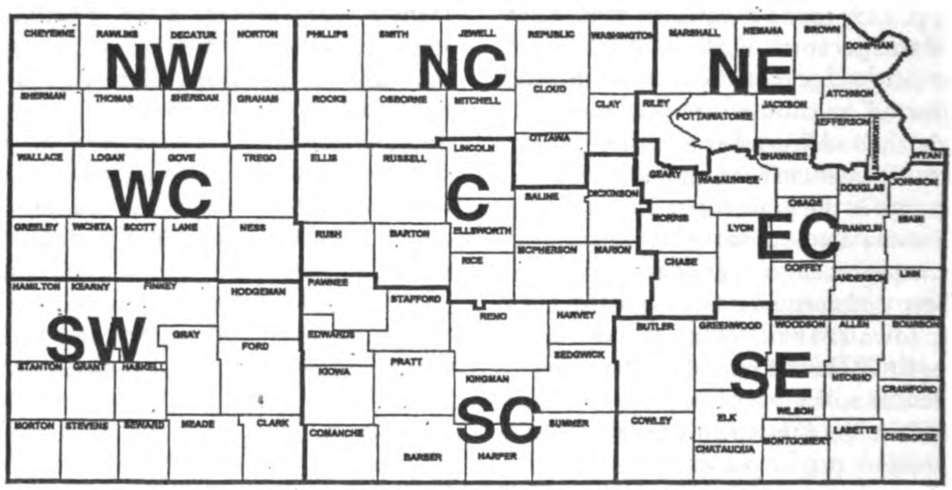
The study area corresponds to the western two-thirds of Kansas encompassing the three central and three western Kansas crop reporting districts (see Figure 1). During the 1998-2001 period the study area accounted for 91.2% of total Kansas wheat production, 79.6% of the state's sorghum production, 80.9% of Kansas corn production, and 38.9% of the soybean output. The study area produced 81.6% of Kansas production of the four crops combined (see Table 1).

Four short line railroads serve the study area—Kansas and Oklahoma Railroad, Kyle Railroad, Cimarron Valley Railroad, and Nebraska, Kansas, and Colorado Railnet. The Kansas Southwestern Railroad began operations in 1991, and the Central Kansas Railroad inaugurated service in 1993. These two railroads merged in June 2000 and became Central Kansas Railway (CKR). The CKR sold its Kansas system to Kansas and Oklahoma Railroad which began operating on June 29, 2001. The Kansas and Oklahoma serves the central part of the study area from Wichita, Kansas west to the Colorado border. It also serves south central Kansas and has a line in north central Kansas as well. The Kansas and Oklahoma Railroad has 971 route miles in Kansas and 108 employees.

The Kyle Railroad serves the northern part of the study area with a 482-mile system. The Kyle began operations in 1982 and has 110 full-time employees. The Cimarron Valley Railroad (CV) has 260 route miles with 186 miles in southwest Kansas. The CV was purchased from the Santa Fe Railroad and began operations in February 1996. The CV has 15 full-time employees in Kansas. The Nebraska, Kansas, and Colorado Railnet (NKC) serves five Kansas counties in the northwest part of the study area. The railroad has 122 miles in Kansas and 17 miles of trackage rights on the Kyle Railroad. The NKC began operations in December 1996 and has 30 full-time employees.

The study area is also served by two Class I railroads, the Burlington Northern Santa Fe (BNSF) and the Union Pacific System (UP). The BNSF has 1,072 miles of main line track

Figure 1: Kansas Crop Reporting Districts



Kansas is divided into nine agricultural statistics districts for convenience in compiling and presenting statistical information on crops and livestock. These nine districts are outlined on the above map. The districts are designated as follows: Northwest (NW), West Central (WC), Southwest (SW), North Central (NC), Central (C), South Central (SC), Northeast (NE), East Central (EC), and Southeast (SE).

Table 1: Study Area Grain Production, 1998 – 2001 (thousands of bushels)

Year	Wheat	Corn	Sorghum	Soybeans	Total
1998	452,488	342,565	206,672	26,277	1,028,002
1999	407,378	359,505	210,216	33,025	1,010,124
2000	311,785	325,745	142,322	23,738	803,590
2001	290,910	297,710	192,135	31,069	811,824
Total	1,426,561	1,325,525	751,345	114,109	3,653,540

Sources: (1998) *Kansas Department of Agriculture,* Kansas Farm Facts 2000. *(1999 and 2000) Kansas Department of Agriculture,* Kansas Farm Facts 2001. *(2001) Kansas Department of Agriculture, Kansas Farm Facts 2002.*

in Kansas and 188 branchline miles. The UP has 1,378 main line miles and 127 branchline miles.

DESCRIPTION OF THE KANSAS WHEAT LOGISTICS SYSTEM

Figure 2 portrays a simplified version of the Kansas wheat logistics system. Wheat is shipped from farms primarily in five axle, 80,000-pound semitractor trailer trucks (hereafter referred to as semitruck) to country grain elevators, which are usually no more than 10 to 15 miles from the farm origin. Wheat is shipped from country elevators to either shuttle train stations (100-railcar shipping facilities at former country elevator locations) or the terminal elevators at Salina, Wichita, and Hutchinson, Kansas. Wheat moves exclusively by semitruck to shuttle train stations, but movements to Salina, Wichita, and Hutchinson can be semitruck, short line railroad and Class I railroad. Wheat is then shipped by Class I unit train from the shuttle train facilities and the grain terminal elevators in Salina, Wichita, and Hutchinson to Houston, Texas for export.

As noted above, this is a simplified version of the wheat logistics system. In some cases, farmers deliver wheat by semitruck directly to shuttle train stations or Salina, Wichita, and Hutchinson grain terminals. This occurs if the farm origins are relatively close to one of these facilities. Also Kansas wheat is shipped to many domestic flour milling locations, as well as the Texas Gulf region for export.

THE MODEL

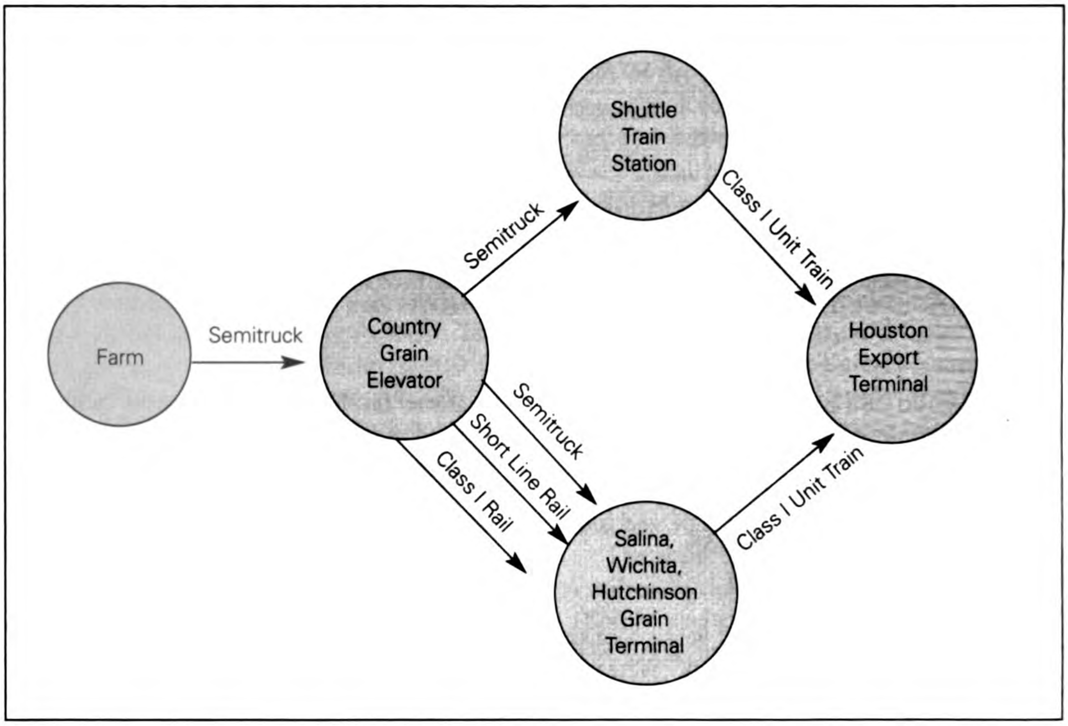
The road damage cost analysis discussed in this paper is part of a larger study that measured changes in wheat transportation and handling costs, road damage costs, and highway safety costs and benefits, resulting from simulated short line railroad abandonment in Kansas. In order to understand the road damage cost analysis, it is necessary to discuss the wheat logistics network model which generated data inputs for the road damage cost model.

Wheat Logistics Network Model

The movement of Kansas wheat is modeled as a transshipment network model with individual farms serving as supply nodes, grain elevators, and unit train loading facilities serving as transshipment nodes, and the final demand node being the export terminals at Houston, Texas. The county and state road networks, short line railroads, and Class I railroads constitute the arcs which connect these nodes.

Given the magnitude and complexity of the wheat logistics system, the movement of

Figure 2. Wheat Logistics System



Kansas wheat through the various possible network routes is most clearly analyzed in four distinct steps. Step I involves the collection of wheat from production origins, or farms, into an intermediate storage facility (grain elevator) which can ship wheat to the terminal node represented by Houston in the wheat logistics system model. Since it is not economically feasible for firms to ship wheat by truck from Kansas to Houston, Step I consists of moving wheat from the farm to an elevator that has rail access capable of reaching Houston. Step II involves the handling of wheat at intermediate storage facilities. Step III analyzes the shipment of wheat from Kansas unit train shipping facilities to the network model final demand node represented by the Port of Houston. Step IV is the same as Steps I to III except short line railroads are assumed to be abandoned.

Although profit maximization is assumed to be the main goal of all agents (farmers, elevators, transport firms) in the wheat logistics system, costs serve as the most consistent influence on agents' behavior. Therefore, it is assumed that all agents in the system seek to minimize the costs involved in shipping wheat to market. Farmers attempt to minimize both the financial and time costs of getting wheat from the field to the grain elevator or unit train facility; grain elevators and unit train shipping facilities operate in order to minimize the cost of handling wheat and shipping it to various market destinations. Thus, the goal of the model is to determine the least cost transport route for Kansas wheat from production origin to final destination utilizing the available transportation network. The Port of Houston is assumed to approximate the cost of shipping Kansas wheat to the many destinations to which it is normally shipped in a given year.[9] It is assumed that all agents minimize the costs involved in shipping wheat to market. This relationship is summarized in mathematical form by the following objective function:

(1) Minimize $TSC = \sum_i (H_i + T_i + R_i)X_i$

Subject to the following constraints:

$H_i, T_i, R_i > 0$

Total Wheat Demanded = Total Wheat Supplied

Actual Wheat Stored at Elevator i ≤ Maximum Storage Capacity of Elevator i

Actual Transport by Truck i ≤ Maximum Transport Capacity of Truck i

Actual Transport by Railcar i ≤ Maximum Transport Capacity of Railcar i

Flow of Wheat into Elevator i = Flow of Wheat out of Elevator i

Where:

TSC is the total wheat logistics system transportation and handling costs

H_i is the sum of all handling costs of unit of wheat i

T_i is the sum of all trucking costs of unit of wheat i

R_i is the sum of all rail costs of unit of wheat i

X_i is the total amount of wheat shipped from Kansas farms to the Port of Houston.

See Babcock, Bunch, Sanderson, and Witt (2003) for a detailed discussion of the wheat logistics model.

The Road Damage Cost Model

Before discussing the pavement damage model, it is necessary to consider the pavement management process. The performance of a pavement is measured by its present serviceability rating (PSR). The PSR rating is a quality index with five (5.0) being the best possible pavement condition and zero being the worst. The Kansas Department of Transportation (KDOT) policy is to design and build asphalt pavements to an initial PSR of 4.2 and requires a mandatory reconstruction of an asphalt pavement when its PSR reaches 2.5 or lower. Roads are initially designed to accommodate forecasted traffic volumes, and the PSR of a road is expected to decline over time with a progressive number of cumulative vehicle passes. Thus, a pavement begins with an initial PSR of 4.2 and steadily declines with time and vehicle passes until it reaches the terminal PSR of 2.5 when the entire road must be reconstructed. KDOT further extends the lives of its asphalt pavements by conducting substantial maintenance in the interim to raise the PSR of the pavement prior to it reaching its terminal PSR. In fact, current KDOT practice is to perform substantial maintenance on a pavement, on average, at the 10- and 20-year point in a pavement lifecycle which thereby extends the maximum feasible life of asphalt pavements on the state highway network to 30 years.

This study uses the methodology developed by Denver Tolliver (2000). The Tolliver model has four main steps and utilizes the road damage functions estimated by American Association of State Highway and Transportation Officials (AASHTO) studies.[10] First, the load characteristics of a standard grain truck are converted to an equivalent single axle load (ESAL) measurement which indicates the damage that the standard loaded grain truck will inflict upon a specific pavement segment compared to that caused by a pass of the standard 18,000-pound tandem axle utilized in AASHTO studies. Thus, a 1.2 ESAL axle pass will cause 1.2 times the damage as a standard 18,000-pound axle. Pavement damage is evaluated in terms of loss in PSR and is dependent upon the structural number (SN) of a pavement segment, as well as upon the weight and load configurations of a standard grain truck. The structural number is a measure of the thickness of the pavement that has been adjusted in terms of its strength based upon the materials comprising the pavement design. The structural number gives an indication of how well a pavement will bear an ESAL pass and gives an indication of the design life of a pavement in terms of the total number of ESAL passes it will bear before its terminal serviceability is reached.

The second step in the Tolliver model is to determine the design life of a pavement segment as defined in terms of the total number of ESAL passes it can sustain before its serviceability declines below its terminal PSR. The ESAL life equations are derived from the same AASHTO equations used to determine the ESAL factors calculated in Step 1. This calculation provides the total ESAL life of a pavement section and is the chief input to Step 3 of the model.

Step 3 is to determine and apply the cost per ESAL to the pavement segments impacted by abandonment. Based on pavement life cycle cost data obtained from KDOT, we know the total life cycle cost of a pavement segment. From the ESAL calculation in Step 2, we know how many ESAL passes comprise the pavement's feasible life, or ESAL life of the pavement. By dividing the total life cycle pavement cost by the ESAL life of the pavement segment, the cost per ESAL mile is determined for a road segment. Thus, by multiplying the cost per ESAL mile by the length of the road segment impacted by abandonment and by the total number of ESAL passes expected upon the pavement, the total damage cost for a pavement segment is estimated.

Step 4 of the Tolliver model involves adjusting the total damage cost for a road segment, so that it does not include the pavement deterioration that occurs naturally over the 30-year life of a pavement. The environmental damage function is modeled as a negative exponential function and predicts large environmental deterioration in the early life of a pavement which deteriorates at a decreasing rate as the pavement ages. Tolliver's model estimates a decay rate by determining the deterioration rate that would be necessary to erode the serviceability of a pavement segment from the initial PSR of a road to its terminal PSR over the maximum feasible life of the pavement section. This decay rate is then applied to the typical pavement performance period to determine PSR expected to be lost to the environment. The PSR lost to the environment is translated into the percentage of total PSR decline by dividing the PSR lost to the environment by the difference between initial and terminal PSR. For instance, if the environment is expected to deteriorate an impacted pavement by .85 PSR points and the difference between initial and terminal PSR is 1.7, then environmental damage would be estimated to be 50% of the total pavement damage. The total pavement damage cost estimate is reduced by this percentage to yield the damage caused by abandonment-related truck traffic.

As noted above, the Tolliver methodology begins with converting the load characteristics of a standard grain truck to an equivalent single axle load (ESAL) measurement, which indicates the damage that the standard loaded grain truck will inflict upon a specific pavement segment, compared to that caused by a pass of the standard 18,000-pound tandem axle used in the AASHTO studies. In order to utilize the AASHTO functions, the load characteristics for a typical grain truck had to be converted into 18,000- pound equivalents. Axle load equivalency factors were calculated for the standard grain tractor-trailer configuration. The typical grain semitruck has one single-axle load and two tandem axle loads. Standard loaded grain truck weight was estimated to be 80,000 pounds configured with 10,000 pounds on the front single axle and 34,000 pounds on both the second and third tandem axles. The pavement deterioration caused by the grain semitrucks was calculated as follows:

First, the pavement deterioration caused by the front single-axle load was calculated in comparison to the damage expected from a standardized single 18,000-pound axle using the following AASHTO damage function:

(2) $\log_{10}(ESAL) = 4.79 \log_{10}([L+1] / [18 + 1]) + (G / B_{18}) - (G / B)$

where

L = 10 (10,000 pounds)

$B_{18} = 0.4 + [1{,}094 / (SN+1)^{5.19}]$

and where

B_{18} = rate of deterioration resulting from a single 18,000-pound axle

SN = structural number of flexible pavement section

(3) $$B(\text{equation } 2) = 0.4 + \frac{0.081(L+1)^{3.23}}{(SN+1)^{5.19}}$$

where

B = rate of deterioration for a given axle

(4) $G(\text{equation } 2) = \log 10 ([P_I - P_T) / [P_I - 1.5])$

where

P_I = initial pavement serviceability rating

P_T = terminal pavement serviceability rating

Then, the actual ESAL factor for the front axle is determined.

(5) $n1 = 10^{\log 10(ESAL)}$

where

n1 = ESAL factor for single front axle

Second, the deterioration caused by the tandem-axle loads in comparison to a standard 18,000-pound axle load was estimated using the following relationship:

(6) $\log_{10}(ESAL) = 4.79 \log_{10}([L + 2] / [18 + 1]) - 4.33 \log_{10}(2) + (G / B_{18}) - (G / B)$

where

L = 34 (34,000 lbs)

$B_{18} = 0.4 + [1{,}094 / (SN + 1)^{5.19}]$

and where

B_{18} = rate of deterioration for a single 18,000-pound axle

SN = structural number of flexible pavement section

(7) $$B(\text{equation } 6) = 0.4 + \frac{0.081(L+2)^{3.23}}{(SN+1)^{5.19} 2^{3.23}}$$

where

B = rate of deterioration for a given axle

(8) $G(\text{equation } 6) = \log 10 ([P_I - P_T] / [P_I - 1.5)$

where

P_I = initial pavement serviceability rating

P_T = terminal pavement serviceability rating

Then, the actual ESAL factor for the loaded rear tandem axles was determined.

(9) $n2 = 10^{\log 10(ESAL)}$

where

n2 = n3 = ESAL factor for loaded rear tandem axles

Third, the ESAL, or pavement damage factor, for an individual grain semitruck on each impacted segment was determined by summing the ESAL factors for each of the axles.

(10) ESALtruck = n1 + n2 + n3

The second step of the Tolliver model is determination of the design life of a pavement segment defined in terms of the total ESALs it can sustain before its serviceability falls below its terminal PSR.

The maximum life of an impacted pavement is determined by computing the difference between the initial serviceability rating and the terminal serviceability rating. Flexible pavements in Kansas are designed to have an initial PSR of 4.2 and a terminal PSR of 2.5. Thus, the maximum tolerable decline in PSR (MPSRD) is calculated as

(11) $MPSRD = P_I - P_T$

$= 4.2 - 2.5$
$= 1.7$

The maximum feasible life of pavement affected by abandonment-related truck traffic is defined in terms of years by estimating how long it will take a pavement to decline to the minimum allowable PSR in the absence of truck traffic. The typical pavement performance period for an asphalt pavement section is about 10 years. However, by performing substantial maintenance, usually in the form of an asphalt overlay, the life of a flexible pavement can be dramatically extended. Thus, performing substantial maintenance at 10 and 20 years extends the maximum feasible life for asphalt pavement to 30 years.

The life of a pavement is defined in terms of ESALs. The ESAL life of each road segment is the number of axle passes that would cause the pavement to decline to its terminal serviceability rating. Highway Economic Requirements System (HERS) functions developed by the Federal Highway Administration are used to compute the ESAL lives of impacted pavement segments as follows:

(12) LGE = XA + (XG / XB)

where

LGE = logarithmic representation of ESAL life

XA = theoretical life of a newly constructed pavement

XB = the rate at which a pavement life is consumed with the accumulation of ESALs

XG = expresses pavement serviceability loss in terms of maximum tolerable decline in PSR

(13) $XA = 9.36 \log_{10} (SNA) - 0.2$

(14) $SNA = SN + (6 / SN)^{0.5}$

SN = structural number of impacted pavement

(15) $XB = 0.4 + (1{,}094 / SNA)^{5.19}$

(16) $XG = \log_{10}([P_I - P_T] / 3.5)$

Thus,

(17) $\text{ESAL Life} = 10^{LGE}$

The goal of Step 3 of the Tolliver methodology is determination of the total pavement damage cost for each impacted pavement segment. The first step in this process is calculation of the cost per ESAL mile for each pavement segment. This is accomplished by dividing the total life cycle pavement cost by the ESAL life of the pavement segment to obtain equation (18).

(18) ESAL Cost per Mile = Repair Cost per Mile / ESAL Life

where Repair Cost per Mile = Sum of one reconstruction and two substantial maintenance treatments.

Total pavement damage costs are then obtained by multiplying ESAL cost per mile (equation 18) by the length (miles) of the impacted road segment, and then multiplying the result by the number of abandonment-related ESAL passes generated on a road segment. The total abandonment-related ESALs impacting a pavement section is equal to the number of ESALs per grain truck on that particular section of pavement (from equation 10)) multiplied by the total number of grain trucks anticipated to be traveling upon that segment of pavement following simulated short line abandonment (obtained from the network model).

(19) Abandonment-Related ESALs = ESALtruck x Abandonment-Related Truckloads

The total pavement damage cost for a pavement segment is obtained by multiplying the ESAL cost per mile (equation 18) by the abandonment-related increase in ESALs (equation 19) by the total length (miles) of the pavement segment.

(20) Total Damage Cost = (ESAL Cost per Mile) x (length of pavement) x (Abandonment-Related ESALs)

Step 4 of the Tolliver method involves adjusting the total damage cost for a pavement segment, so that it does not include the environment-related deterioration that occurs during the 30-year life of a pavement. A time decay function is used to estimate how much loss in PSR would occur due to environmental factors.

(21) $P_E = P_I \times e^{(t\delta)}$

where

(22) $\delta = (-\ln[P_T / P_I]) / L$

P_E = PSR lost to the environment

δ = decay rate due to environmental losses

P_T = terminal PSR

P_I = initial PSR

L = 30 = maximum feasible life of pavement section

t = 10 = typical pavement performance period

The percentage of PSR decline due to the environment relative to total tolerable decline in PSR is calculated as follows:

(23) $\text{EnvDamage} = P_E / (P_I - P_T)$

After ESAL cost per mile was adjusted by equation (23), total abandonment-related road damage cost impacts were calculated by summing the total damage cost of increased truck traffic per road segment (equation 20) for each state highway pavement segment impacted by simulated abandonment of short line railroads.

DATA

The Tolliver model discussed above requires truck configuration data. It is assumed that all grain hauling trucks are five-axle, semi-tractor trailers with loading configurations assumed to be 10,000 pounds on the front axle and 34,000 pounds for each of the rear tandem axles (i.e., 10/34/34). This configuration was identified by KDOT as being typical based on previous KDOT research.

Several data inputs are required for each pavement segment in the Kansas highway system. KDOT maintains a database of 11,254 pavement segments which constitute the state highway system called CANSYS. With one exception, all of the data inputs required to estimate the Tolliver model are found in CANSYS including:

- Length of pavement segment
- Structural number (SN)
- Initial PSR (P_I)

- Terminal PSR(P_T)
- Maximum feasible life of payment segment in years (L)
- Remaining 18,000-pound loads until substantial maintenance or reconstruction is required.

The only data input not contained in CANSYS is typical pavement performance period which is the number of years after which a new pavement is resurfaced. KDOT pavement performance period is 10 years for flexible pavements. All the pavement segments in the model are assumed to be flexible.

In Kansas, new state highways are constructed to an initial PSR of 4.2, and KDOT uses a value of 2.5 as terminal PSR. Thus, the maximum life of a pavement segment in terms of tolerable decline in PSR is 1.7 (4.2 - 2.5). It is also necessary to calculate the maximum feasible life of a road segment in terms of years, or the time it takes for the pavement to deteriorate from the initial PSR to the terminal PSR in the absence of truck traffic. This is determined by KDOT management policies. A new pavement segment receives substantial maintenance after 10 years and after 20 years, and is reconstructed after 30 years. Therefore, the maximum feasible life (L) of a pavement segment is 30 years.[11]

The sum of the two substantial maintenance treatments and the reconstruction is the repair cost per mile used in equation (18). In 1999, KDOT reconstructed 200 miles of pavement in Kansas at a total cost of $250 million, or $1.25 million per mile. KDOT also performed 1,400 miles of substantial maintenance in 1999 at a total cost of $150 million, or $107,143 per mile. Repair cost per mile is the sum of two substantial maintenance treatments ($214,286) and one reconstruction ($1,250,000), or $1,464,286 per mile.

The final data inputs required to estimate the road damage costs caused by short line railroad abandonment are the rail carloadings for each station on the study area short line railroads. This data is provided by the wheat logistics network model described above. The carloadings at each station were converted to truckloads in the post-abandonment scenario at a ratio of one carload equals four truckloads.

EMPIRICAL RESULTS

In the post-abandonment scenario, the wheat logistics network model routes the abandonment-related truckloads from each station on a study area short line to the nearest unit train shipping location. The Tolliver model coupled with the CANSYS database is employed to measure the road damage costs of the trucks traveling on these routes.[12] The results are in Table 2.

An examination of Table 2 indicates that total annual road damage costs resulting from simulated abandonment of study area short lines are $57.8 million. Abandonment of the Kansas and Oklahoma Railroad results in $30.6 million in annual road damage costs. The incremental truck traffic generated by the abandonment of the Cimarron Valley Railroad, the Kyle Railroad and the Nebraska, Kansas, and Colorado Railnet (NKC) resulted in annual road damage costs of $15.8 million, $8.5 million, and $2.9 million, respectively. Thus, the Kansas and Oklahoma Railroad accounts for 52.9% of the total road damage costs. The percentages for the Kyle, Cimarron Valley, and NKC railroads were 27.3%, 14.8%, and 5%, respectively.

Other information is presented in Table 2. The truck miles are the incremental truck traffic generated by simulated abandonment of each study area short line. Total abandonment-related truck miles were 8.1 million. A total of 1,761 short line miles were assumed to be abandoned, generating truck traffic that impacted nearly 2,400 miles of Kansas highways. Average road damage cost per

Table 2: Road Damage Impacts by Railroad—State Highways

Railroad	Truck Miles	Miles of Highway Impacted	Miles of Rail Abandoned	Annual Road Damage Costs: Total Cost	Cost Per Truck Mile	Cost Per Rail Mile Abandoned
Kansas and Oklahoma	3,783,388	1,095	971	$30,564,897	$8.08	$31,478
Kyle	2,105,920	735	482	$15,763,173	$7.49	$32,704
Cimarron Valley	1,482,652	300	186	$8,534,025	$5.76	$45,882
Nebraska, Kansas and Colorado	706,908	269	122	$2,918,321	$4.13	$23,921
All Short Lines Total	8,078,868	2,399	1,761	$57,780,416	$7.15	$32,811

truck mile related to the abandonment of the various short lines ranged from a low of $4.13 to a high of $8.08, and an average for the entire study area of $7.15. The average road damage cost per mile of study area short line railroad abandoned was $32,811.

Abandonment-Related Truck User Fees

The increase in truck traffic resulting from short line railroad abandonment will generate an increase in highway user fees. For example, Kansas levies an annual registration fee of $1,725 for a truck in the 80,000-pound class. It is not possible to determine how much of the incremental trucking demand related to short line abandonment would be served by entry of additional trucking firms and how much of that demand would be served by firms already in the industry. Thus, incremental revenue from truck registration fees was not estimated. However, Kansas also levies a 25-cent tax per gallon on diesel fuel.

The incremental fuel tax revenue generated by short line abandonment is calculated in the following manner. The 25-cent per gallon diesel fuel tax is multiplied by the abandonment- related truck miles of 8,078,868 (see Table 2). According to Berwick and Dooley (1997), fuel consumption for 80,000-pound semitrucks is about seven miles per gallon. The previous result ($2,019,717) is divided by seven miles per gallon to obtain the total incremental diesel fuel tax revenue of $288,531. Obviously, this tax revenue offsets only a small part of the $57.8 million of road damage costs generated by simulated short line abandonment.[13]

CONCLUSION

Structural changes have occurred in the Kansas wheat logistics system that have increased trucking of wheat and correspondingly reduced short line railroad wheat traffic. Grain is the principal commodity market of Kansas short lines and carloads per mile of track is the primary determinant of short line railroad profitability. Thus, as short lines lose market share in their principal commodity market, their long-term viability is threatened.

Abandonment of short line railroads could have several negative effects on rural communities including lower grain prices for farmers, higher transport costs for rail shippers, loss of market options for rural shippers, lost economic development opportunities for rural communities, loss of tax revenue, and increased damage costs on county roads and state highways.

Given the potential negative effects of short line railroad abandonment, it is important to measure the quantifiable aspects of abandonment. This paper measured the change in Kansas state highway damage costs, resulting from assumed abandonment of short line railroads. This was achieved through the use of a wheat logistics network model that reveals the number of wheat carloadings at each station on each of the short line railroads in the study area.

Abandonment of the short line railroads was assumed and the short line railroad wheat carloadings at each station were converted to truckloads at a ratio of one carload equals four truckloads. A road damage cost model developed by Denver Tolliver was used to calculate the road damage costs for state highways attributable to the increased wheat trucking following simulated short line abandonment.

Total annual road damage cost resulting from simulated abandonment of study area short lines was $57.8 million. Of this total, the Kansas and Oklahoma Railroad accounts for 52.9%; the Kyle Railroad, 27.3%; the Cimarron Valley Railroad, 14.8%; and the Nebraska, Kansas and Colorado Railnet, 5%. The average road damage cost per truck mile for the entire study area was $7.15, and the average road damage cost per mile of short line abandoned was $32,811. Incremental state fuel tax revenue generated by short line abandonment was only $288,531, or 0.5% of the $57.8 million in annual road damage cost.

State and federal financial assistance to short line railroads would be an efficient use of resources if short line rail transportation results in external benefits. This is the case because the market always underallocates resources to markets with external benefits. This study found that short line externalities can be substantial since abandonment of all the short lines in the study area would increase Kansas road damage costs by nearly $58 million annually. Other potential external benefits of short line transport are highway safety benefits (due to reduced number of large trucks on the highway system) and environmental benefits due to lower emissions. Further research is needed to measure the value of these external benefits from a national perspective.

Endnotes

1. In this study, short line railroads are defined as including Class II and III railroads as defined by the Surface Transportation Board. In 2001, Class II railroads were classified as railroads with operating revenue of $21.3 to $266.6 million, and Class III railroads were those with less than $21.3 million of operating revenue (*Association of American Railroads* 2002, p. 3).

2. See *Association of American Railroads* (2002, p. 3).

3. Kansas Department of Transportation (2002, p. 35).

4. Kansas Department of Transportation (2002, pp. 82-85).

5. Kansas Department of Transportation (2002, p. 85).

6. Kansas Department of Transportation (2002, p. 84-85).

7. Kansas Department of Transportation (2002, p. 85).

8. Babcock and Bunch (2002, pp. 34-35).

9. Texas Gulf ports, of which Houston is the largest, is the most important single destination of Kansas wheat, accounting for about 50% of the shipments [*Kansas Agricultural Statistics* (2001, pp. 13 and 15), and *Kansas Agricultural Statistics* (2002, pp. 13 and 15)].

10. The AASHTO study was an empirical study in which a panel of test drivers made quality assessments of their ability to safely operate their vehicles on test pavements that were in varied states of decay.

11. Based on conversations with Ricky Miller of the KDOT Bureau of Materials and Research.

12. Pavement impacts are measured only for loaded truck miles. This assumption is reasonable since pavement impacts from empty miles are negligible.

13. The study only measures road impacts generated by loaded truck miles. However, actual user fee revenue is generated from both empty and loaded miles. If it were assumed that empty miles generated the same revenue as loaded miles ($288,531), net road damage cost would only be reduced from $57.8 million to $57.2 million.

References

Association of American Railroads. *Railroad Facts, 2002 Edition.* Washington, DC, 2002.

Babcock, Michael W., E.R. Russell, M. Prater, and J. Morrill. *State Short Line Railroads and the Rural Economy.* Topeka, Kansas, Kansas Department of Transportation, 1993.

Babcock, Michael W., M. Prater, and E.R. Russell. *Long Term Profitability of Grain Dependent Short Line Railroads in the Midwest.* Topeka, Kansas, Kansas Department of Transportation, 1997.

Babcock, Michael W., and James L. Bunch. *Impact of Kansas Grain Transportation on Kansas Highway Damage Costs.* Topeka, Kansas, Kansas Department of Transportation, 2002.

Babcock, Michael W., J.L. Bunch, J. Sanderson, and J.Witt. *Economic Impacts of Railroad Abandonment on Rural Kansas Communities.* Topeka, Kansas, Kansas Department of Transportation, 2003.

Baumel, C.P., J.P. Gervais, H. Hommes, and C. O'Riley. *The Iowa Grain Flow Survey: Where and How Iowa Grain Producers and Country Elevators Ship Corn and Soybeans.* Ames, Iowa, Iowa State University, 1996.

Berwick, Mark, and Frank Dooley. *Truck Costs for Owner/Operators,* MPC 97-81. Mountain Plains Consortium, North Dakota State University, 1997.

Casavant, Kenneth L., and J.C. Lenzi. "Preparing for Rail Line Abandonment. Prediction of Financial and Location Impacts on Roads." *Journal of the Transportation Research Forum* 30 (1990): 264-274.

Eusebio, Victor E., and S.J. Rindom. "Methodology for Estimating Road Damage Cost Resulting from Potential Rail Branchline Abandonment: The Case of South Central Kansas." *Transportation Research Record* 1305 (1991): 153-159.

Fuller, Stephen, T.H. Yu, D. Collier, J. Jamieson, and R. Harrison. *Texas Grain Transportation Study.* Austin, Texas, Center for Transportation Research, The University of Texas at Austin, and Department of Agricultural Economics, Texas A&M University, 2001.

Kansas Agricultural Statistics Service, Kansas State Board of Agriculture. *Kansas Grain Marketing and Transportation.* Topeka, Kansas, 1991.

Kansas Agricultural Statistics Service, Kansas State Board of Agriculture. *Kansas Grain Transportation.* Topeka, Kansas, 2001.

Kansas Agricultural Statistics Service, Kansas State Board of Agriculture. *Kansas Grain Transportation.* Topeka, Kansas, 2002.

Kansas Agricultural Statistics Service, Kansas State Board of Agriculture. *Kansas Farm Facts.* Topeka, Kansas, 2000, 2001, and 2002.

Kansas Department of Transportation, Division of Planning and Development, Office of Rail Affairs. *Kansas Rail Plan Update 2001-2002.* Topeka, Kansas, 2002.

Machalaba, Daniel, "High Speed Grain Terminals Bode Change for Rural U.S." *The Wall Street Journal,* December 26, 2001, Section B1, p. 2.

Nolan, J., M. Khakbazan, R. Gray, and M. Fulton. *Economic Issues Surrounding the Viability of Short Line Railways in the Canadian Prairies.* Saskatoon, Saskatchewan, Department of Agricultural Economics, University of Saskatchewan, 2000.

Rindom, S.J., J.J. Rosacker, and M. Wulfkuhle. *The Transportation Impact of Grain Subterminals in Kansas.* Topeka, Kansas, Kansas Department of Transportation, Bureau of Rail Affairs, 1997.

Russell, Eugene R., M.W. Babcock, and C.E. Mauler. "Study of the Impact of Rail Abandonment on Local Roads and Streets." *Conference Proceedings, Sixth International Conference on Low Volume Roads, Volume I* (1995): 110-119.

Tolliver, Denver, and HDR Engineering Inc. *Benefits of Rail Freight Transportation in Washington: A Multimodal Analysis, Appendix D,* Washington State Department of Transportation, 2000.

Tolliver, Denver, K. Andres, and B. Lindamood. *Washington Rail Impact Analysis: Executive Summary.* Washington State Department of Transportation, 1994.

Upper Great Plains Transportation Institute. "Strategic Transportation Analysis Study Show Results." *UGPTI Insights.* Fargo, North Dakota, Upper Great Plains Transportation Institute, North Dakota State University (Fall 2001): 4-6.

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