

Methodology for Estimating Road Damage Cost Resulting from Potential Rail Branch Line Abandonment: The Case of South Central Kansas

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A systematic procedure is developed to estimate additional highway costs associated with rail branch line abandonment. The procedure is tested in an area in south-central Kansas where three Missouri Pacific (MP) branch lines were recently placed in the Interstate Commerce Commission's Category I abandonment classification. Results suggest that the procedure can be used to estimate additional damages to county, municipal or city, and state road systems resulting from branch line abandonment. Abandoning the three MP branch lines in south-central Kansas will result in an estimated additional annual truck damage to Kansas rural highways amounting to \$138,274 for farm-to-elevator movements of grain. Incremental road damage cost caused by rail abandonment is estimated at \$55,961 per year for intercity grain traffic. The procedure also reflects the abilities of intercity and farm-to-elevator road systems to absorb additional grain traffic resulting from branch line abandonments. An additional bushel of grain moved 1 mi by truck is estimated to cause additional damage to roads amounting to 0.90 cent for farm-to-elevator routes while costing only 0.17 cent for intercity routes. A combination of local roads, collectors, and minor arterials generally composes a farm-to-elevator route, whereas a combination of minor and major arterials and Interstates composes an intercity route. The same procedure can be used to estimate incremental road maintenance costs of rail abandonment for other types of traffic.

Loss of rail service is often met with trepidation by residents of rural communities in Kansas despite contentions by rail carriers that many of the so-called "light-density" rail branch lines are highly unprofitable to operate. To farmers, it could mean an increase in trucking costs as they would have to truck their grains farther to remaining rail heads for marketing. To local shippers, it could mean loss of business and cutbacks in elevator profit margins in order to remain competitive with local elevators having rail connections. To the rural community, it could mean loss of jobs, a decline in general farm incomes, and decreases in land values, as well as increased air pollution and potential safety hazards associated with additional truck traffic. At the state level, it could mean hastened deterioration of rural highways and bridges from additional truck tonnage and the accompanying strain on local and state highway budgets.

State and local planners and policymakers have much cause for concern from the trend toward rail abandonments in Kan-

sas. From 1980 to 1988, a total of 39 Kansas abandonments occurred involving 537 mi of track. Another 348 mi has been placed by the major railroads under various abandonment categories (49 CFR 1152). Some 3,000 mi of rail in Kansas are classified as light density. Shifts in freight traffic from rail to trucks as a result of rail branch line abandonment could be substantial. Additional road maintenance expenses associated with increased truck tonnage could reach major proportions.

Cassavant and Lenzi (1) developed a methodology to predict and estimate damages on rural roads of potential rail line abandonments. Their conceptual model was applied in a case study involving the abandonment of the Mansfield rail line in Washington state.

A similar issue with a different estimation procedure is addressed. Firstly, rather than relying on shipper surveys, a network model is used to generate grain movement data before and after rail abandonment. Shipper cost minimization is the organizing principle for estimating traffic patterns. Second, the Highway Performance Monitoring System (HPMS) pavement damage functions are used instead of the American Association of State Highway and Transportation Officials (AASHTO) pavement functions to more accurately predict pavement life cycles on low-capacity roads. Third, additional damages to Kansas roads by trucks are estimated for changes in intercity as well as farm movements of grain. Last, damage cost estimates are categorized by (a) road systems (i.e., county, municipal or city, and state), to trace the level of government jurisdiction; and (b) road type (i.e., Interstate, arterial, collector, and local), to reflect differences in structure and design among Kansas roads.

A major change in transportation alternatives, such as one triggered by branch line abandonment, can cause shifts in grain flows at both production and local elevator levels. In competitive grain markets, farmers will sell their produce to elevators with the highest local bid for their grains. With rail branch line abandonment, elevators with rail connections (and cheaper shipping costs) are in a position to offer higher bids to farmers. Also, elevators that lost rail service are forced to truck their grains, often at substantially higher costs, to other elevators with rail service or to terminal elevators. The impacts of these changes on rural roads are two-fold. First, farmers will travel longer distances to get the best bid for their grains. This additional mileage means additional use and

damage to the state's rural roads. Second, trucks will occupy an increasingly important role in the local elevator-to-terminal elevator (intercity) movement of grain. Such a shift in modal alternatives towards trucks will result in a higher frequency of heavy trucks and greater damage to the state's road system.

The question of how much damage a proposed rail branch line abandonment will do to an existing network of county, city, and state roads is an empirical issue. A methodology is needed that will quantify damage to rural highways as a result of rail abandonment. An empirical tool is presented for estimating incremental highway damage caused by rail branch line abandonment. Damage is estimated for county, municipal or city, and state road systems.

The Union Pacific System (UPS) recently placed three Missouri Pacific (MP) branch lines in south-central Kansas under Category I abandonment classification (see Figure 1). These

interconnecting lines (Radium-Conway Springs, Hardtner-Conway Springs, and Turon-Iuka lines) have been chosen for application and illustration of the methodology for estimating incremental highway damage caused by changes in grain traffic flows following rail branch line abandonment.

This study assumes that traffic flows represent minimum cost movements both before and after rail abandonment. Beginning flows are based on the assumption that no unusual deterioration of tracks or service quality had artificially diverted traffic to trucks.

The specific objectives of this study are to

1. Develop a systematic procedure for estimating the incremental highway costs associated with potential rail branch line abandonment,
2. Apply the procedure in a case study area so that its validity and workability can be ascertained, and

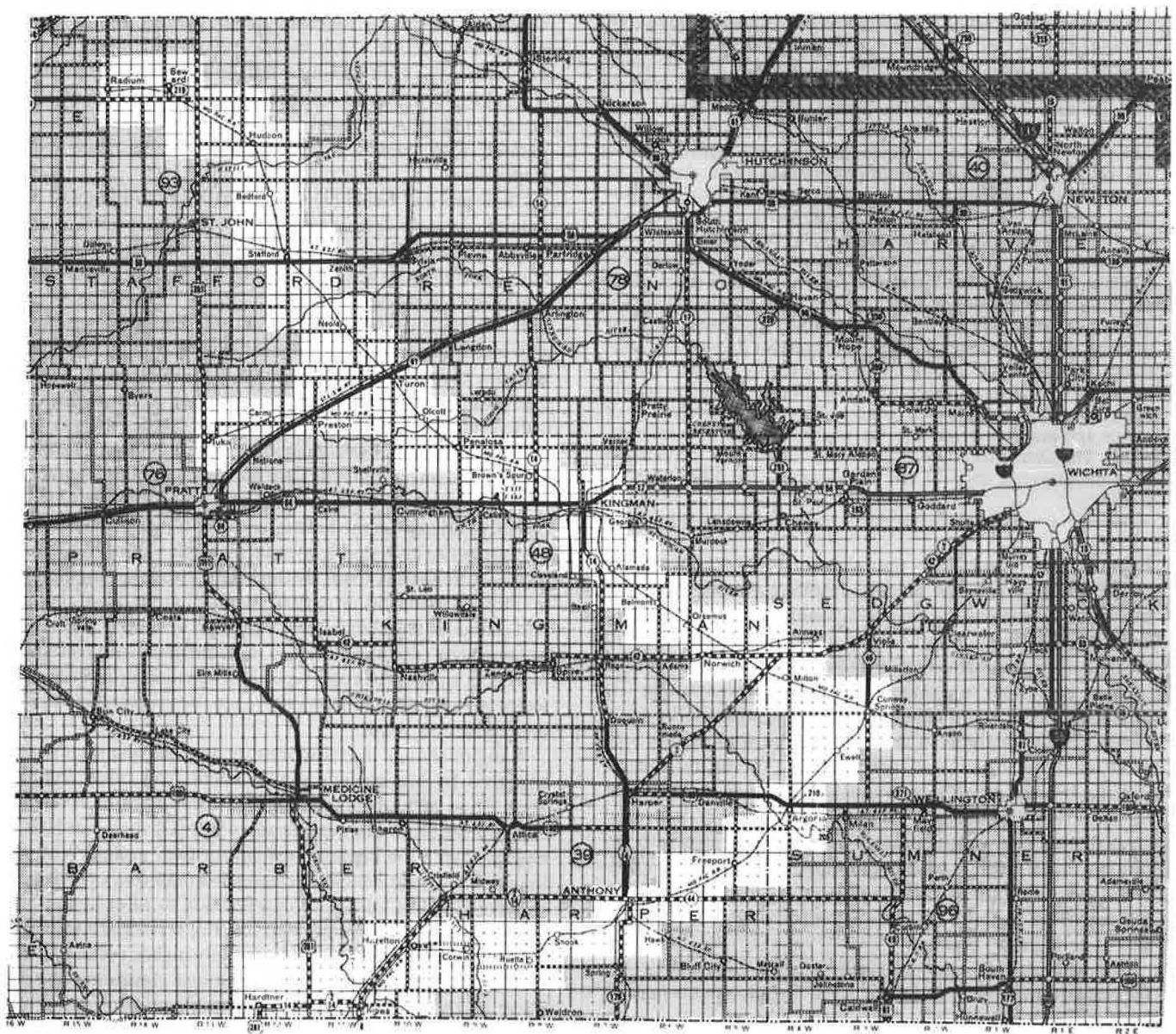


FIGURE 1 Study area.

3. Document the analytical process so that the procedure may be used by other researchers doing similar analyses.

HIGHWAY DETERIORATION PROCESS

There have been many studies (2–5) on the cause-and-effect relationship between heavy truck traffic and the degree of highway deterioration. Truck traffic damage to highways varies mostly with truck axle weight and with specific attributes of the highway such as surface thickness, composition of the surfacing materials used, and soil composition. Climatic conditions also affect highway deterioration rates under given traffic and highway conditions. The combined axle damage associated with a particular truck type and commodity hauled over a specific highway section determines the amount of damage attributed to a truck pass. The accumulation of truck passes over time will eventually result in pavement deterioration and the need for rehabilitation of the highway section.

The effective life of a highway section can be seen as a sequence of cycles in which pavements are constructed or restored to some level of condition from which the deterioration process starts all over again. Pavement repair encompasses a range of potential improvement techniques. However, in most cases, resurfacing or rehabilitation entails an overlay of existing pavement with a new asphalt or concrete surface layer. Pavement overlay is assumed in this study when rehabilitation is required. Increased truck traffic resulting from rail branch line abandonment shortens the lifetime of pavements, thereby increasing the need for frequent rehabilitation.

STUDY AREA

The study area located in south-central Kansas comprises parts of six counties (see Figure 1). It is currently being served at most of its shipping points by the MP railroad. Rail service is also provided at a limited number of shipping points by the Atchison, Topeka, and Santa Fe (ATSF) and the Southern Pacific (SP) railroads. All points in the study area are within 100 mi of at least one of three inland grain terminals: Hutchinson and Wichita, Kansas; and Enid, Oklahoma.

Wheat traffic was chosen for analysis in this study for the following reasons. First, wheat is the dominant grain grown in south-central Kansas. Kansas State Board of Agriculture data for 1988 report 74 percent of total grain acreage in the area planted to wheat. Second, Kansas local elevators normally ship 90 percent or more of wheat received from farmers to destinations outside the community in which the grain is produced (6). Third, rail transportation dominates the transport of Kansas wheat (7). Trucks are readily substitutable for rail on many intrastate movements if rail service is not available or if rail rates are higher than truck rates.

ANALYTICAL PROCEDURES

Transportation Network Model

A network model developed by Chow (8) was used to generate traffic flow data for wheat that moved by truck or by

rail. This model minimizes shipping costs for a predetermined supply of grain when moved from production origins (simulated farms) to demand centers (domestic and export points) via numerous transshipment points (local and terminal elevators). Both intermodal (rail-truck) and intramodal (rail-rail) competition are generated among the transshipment points.

The model is expressed algebraically as follows:

$$\text{Minimize } Z = \sum_{i=1}^F \sum_{j=1}^C a_{ij} WF_{ij} + \sum_{i=1}^C \sum_{j=1}^I (b_{ij} WC_{ij} + b'_{ij} WC'_{ij}) + \sum_{i=1}^I \sum_{j=1}^{P+X} (c_{ij} WI_{ij} + c'_{ij} WI'_{ij})$$

subject to the following constraints:

1. No stocks will remain at the farm or at transshipment points at the end of 1 year.

$$\sum_{i=1}^F WRF_i - \sum_{i=1}^F \sum_{j=1}^C WF_{ij} = 0$$

$$\sum_{i=1}^C WRC_i - \sum_{i=1}^C \sum_{j=1}^I (WC_{ij} + WC'_{ij}) = 0$$

$$\sum_{i=1}^I WRI_i - \sum_{i=1}^I \sum_{j=1}^{P+X} (WI_{ij} + WI'_{ij}) = 0$$

2. All coefficients a_{ij} , b_{ij} , c_{ij} , . . . > 0 .

3. All endogenous variables WF_{ij} , WC_{ij} , WI_{ij} , . . . > 0 .

where

- Z = total shipment and handling cost;
- WF_{ij} = quantity of wheat shipped from Farm i to its next destination j by farm truck;
- WC_{ij} , WC'_{ij} = quantities of wheat shipped from country Elevator i to its next destination j by commercial truck and by railroad, respectively;
- WI_{ij} , WI'_{ij} = quantities of wheat shipped from inland Terminal i to its next destination j by commercial truck and by railroad, respectively;
- a_{ij} = unit shipping cost from Farm i to its next destination j by farm truck;
- b_{ij} , b'_{ij} = unit shipping costs from country Elevator i to its next destination j by commercial truck and by railroad, respectively;
- c_{ij} , c'_{ij} = unit shipping costs from inland Terminal i to its next destination j by commercial truck and by railroad, respectively;
- WRF_i = quantity of wheat received from Farm i ;
- WRC_i = quantity of wheat received from country Elevator i ;
- WRI_i = quantity of wheat received from inland Terminal i ;
- F = number of farms;
- C = number of country elevators;
- I = number of inland terminal elevators;
- P = number of out-of-state processors; and
- X = number of export port terminals.

The network model includes 114 simulated farms, 27 country elevators, 3 inland terminals, 1 out-of-state domestic processing point, and 1 export terminal port. The quantity of wheat supplied by the study area was specified from 1987 county production data. The apportioned quantity of wheat from the study area destined for domestic and export markets was estimated from a grain transportation study by the Kansas State Board of Agriculture (9). The cost of moving grain by farm truck was obtained from an economic engineering study by Chow (10). Commercial truck tariff rates were obtained from the Kansas Motor Carriers Association tariff book (11). Railroad tariff rates from the different local elevator points were obtained from published tariff rates by the Kansas City Board of Trade (12). Rail contract rates out of terminal elevators were obtained from the 1987 Interstate Commerce Commission Carload Waybill Sample Data. Wheat was assumed to move from farms to final destination points during the July 1987 to June 1988 period.

Two sets of grain movement data, each containing specific origin-destination movements by truck, were generated by the network model. The first set was generated from a network model that simulated traffic flow under the assumption of continued MP operations whereas the second set was generated from a model that simulates traffic flow under the assumption of MP branch line abandonment. For each set of data, two types of truck movements were identified: (a) farm to local elevator movement by single-unit, two-axle (SU-2AX) farm trucks over a combination of county, municipal or city, and state road systems; and (b) local elevator to terminal elevator (intercity) movement by commercial five-axle (CO-5AX) trucks over the same combination of roads. For each origin-destination movement of grain by truck, individual highway sections were identified and combined to form the shortest highway route and the total number of annual truck trips over these routes were calculated by dividing total volume of grain moved by the truck capacity. Route identification and total trips were determined for each of the two sets of traffic data generated.

Measuring Pavement Life

Relating road life with degree of road damage requires the use of a common unit of measurement. Thus, the effective life of a highway section and the pavement damage caused by a particular axle configuration and load over the length of the section are expressed in equivalent single-axle loads (ESALs). The effective ESAL life of a highway section can be estimated by the HPMS pavement function as represented by the following equations:

Flexible Pavement

$$\log_{10}(\text{ESALs}) = 9.36 * \log_{10}[\text{SN} + (6/\text{SN})^{0.5}] - 0.20 + G/\beta$$

$$G = \log_{10}[(5 - \text{PSR}_i)/3.5]$$

$$\beta = 0.40 + 1,094/[\text{SN} + (6/\text{SN})^{0.5}]^{5.19}$$

Rigid Pavement

$$\log_{10}(\text{ESALs}) = 7.35 * \log_{10}(D + 1) - 0.06 + G/\beta$$

$$G = \log_{10}[(5 - \text{PSR}_i)/3.5]$$

$$\beta = 1 + 16,240,000/(D + 1)^{8.46}$$

where

SN = pavement structural number, an abstract index that reflects the composite strength of the layers of the flexible pavement section;

D = pavement (slab) thickness;

PSR_i = effective terminal pavement serviceability rating, a composite measure of the highway's condition that, when reached, results in the decision to rehabilitate;

G = damage index, a function of PSR_i; and

β = damage function coefficient as estimated by regression analysis.

Pavement data for each highway section were obtained from the Kansas Department of Transportation's (KDOT's) Bureau of Transportation Planning and from various county engineer's offices in south-central Kansas.

Measuring Road Consumption

The consumption of pavement life constitutes an economic cost. In this study, the concept of short-run marginal cost reflects the additional consumption of fixed highway capacity caused by one more axle pass over a highway section. The marginal cost (in ESALs) of an axle pass is determined for vehicles of different axle groups and loads. The individual marginal costs for each axle group of a truck are then summed to reflect a truck pass for a particular vehicle class. Total road damage attributable to a certain class of traffic is the sum of the costs of all individual truck trips for that class of traffic.

For calculating the degree of road damage of a particular highway section, the average loaded and empty weights for each axle group were obtained from statewide truck weight data.

The AASHO traffic equivalency formulas were then used to convert the average loaded and empty axle loads into axle-specific marginal cost (in ESALs) given the strength and condition rating of each highway section (13). The formulas for single axles are as follows:

Flexible Pavement

$$\log_{10}(N_r/N_x) = 4.79 * \log_{10}(L_x + 1) - 4.79$$

$$* \log_{10}(L_r + 1) + G/\beta_r - G/\beta_x$$

$$G = \log_{10}[(5 - \text{PSR})/3.5]$$

Rigid Pavement

$$\log_{10}(N_r/N_x) = 4.62 * \log_{10}(L_x + 1) - 4.62$$

$$* \log_{10}(L_r + 1) + G/\beta_r - G/\beta_x$$

where

$\log_{10}(N_r/N_x)$ = log of the traffic equivalency formula;

L_r = reference axle weight (18 kips);
 L_x = axle weight (kips); and
 PSR = present pavement serviceability rating.

The corresponding formulas for the tandem axles are as follows:

Flexible Pavement

$$\log_{10}(N_r/N_x) = 4.79 * \log_{10}(L_x + 2) - 4.79 * \log(L_r + 1) \\ - 4.33 * \log_{10}(2) + G/\beta_r - G/\beta_x$$

Rigid Pavement

$$\log_{10}(N_r/N_x) = 4.62 * \log_{10}(L_x + 2) - 4.62 * \log_{10}(L_r + 1) \\ - 3.28 * \log_{10}(2) + G/\beta_r - G/\beta_x$$

The damage function coefficient β is as follows:

Flexible Pavement

$$\beta = 0.40 + 0.081 (L1 + L2)^{3.23} / [(SN + (6/SN)^{0.5})^{5.19} L2^{3.23}]$$

Rigid Pavement

$$\beta = 1 + 3.63(L1 + L2)^{5.20} / [(D + 1)^{8.46} L2^{3.62}]$$

where

$L1$ = the axle load (kips); and
 $L2$ = axle type (1 = the single axle, 2 = tandem axle).

The damage function coefficient β is computed with respect to the reference axle β_r and axle group (β_x), i.e., single or tandem axle.

The empty and loaded ESALs for each axle group were calculated using the preceding formulas. The empty and loaded ESALs were then summed for all axle groups to obtain the degree of road damage per round-trip vehicle-mile traveled (VMT) for a given road segment. The number of annual truck trips for a given road segment (as derived from the network model) multiplied by the road damage (in ESALs) per round-trip VMT equals the total annual damage for the road segment. Two sets of road damage calculations were done to obtain the degree of road damage before and after branch line abandonment.

Measuring Truck Accountability

The cost responsibility of trucks for pavement damage for each road segment is the product of pavement rehabilitation cost per ESAL-mile, road damage (in annual ESALs) and the number of miles for the segment. Estimated pavement rehabilitation costs per mile by road classification were obtained from KDOT's Bureau of Management and Budget. Pavement rehabilitation cost per ESAL-mile was obtained by dividing per-mile pavement rehabilitation cost by the effective ESAL life (as calculated by the HPMS damage function).

Two sets of truck-accountable road damage costs were calculated because of the difference in road use by trucks before

and after rail abandonment. The impact of rail branch line abandonment on rural highways is the difference between the truck-accountable costs before and after abandonment.

RESULTS AND CONCLUSIONS

Abandoning the MP branch lines in south-central Kansas will mean an increase in average distance traveled from farms to study area elevators of from 4.7 to 7.0 mi. Most of the increase in distance traveled can be explained by an increase in wheat moved from farms to elevators retaining rail (ATSF and SP) service. Movement to elevators that lost rail (MP) service is reduced.

Abandoning the MP branch lines in south-central Kansas will mean an additional 740,000 bushels of wheat transported by trucks out of local elevators to terminal elevator transit points for shipments by rail or truck to final destination points. These additional shipments represent a 42 percent increase in grain moved by trucks from local elevators. To some extent, the amount of grain traffic diverted from rails to trucks is held down by increased wheat receipts from local elevators with rail access points to ATSF and SP.

Truck-accountable road damage costs associated with pre- and postabandonment periods for farm-to-elevator and intercity movements are presented in Tables 1 and 2, respectively. These costs are categorized by (a) road system, to reflect the level of government jurisdiction; and (b) road type, to reflect differences in structure and design among Kansas roads. Abandoning the designated branch lines in south-central Kansas is estimated to result in additional annual truck damage to Kansas rural highways amounting to \$138,274, a 43 percent increase in farm-to-elevator delivery truck-accountable costs (see Table 1). Incremental truck damage to roads is attributed to farmers trucking their wheat over longer distances to local elevators—an average increase of 49 percent over the preabandonment period.

Abandoning the designated lines is estimated to result in an additional annual truck damage to Kansas rural highways amounting to \$55,961 for intercity movements of wheat. This amount represents the highway use cost of hauling wheat diverted to trucks, a 24 percent increase in truck damage cost over the preabandonment period. The increase in truck-accountable road damage cost can be attributed to additional truck traffic resulting from grain diversion from rails to trucks.

Last, the cost of rail abandonment was converted in a bushel-mile cost of moving wheat by truck (see Table 3). Abandonment of the branch lines will result in additional truck damage to Kansas rural highways amounting to 0.90 cent per bushel-mile of wheat moved for farm-to-elevator movements and 0.17 cent per bushel-mile moved for intercity movements. Study results indicate that the intercity roads, in general, are better designed to handle increases in traffic than local roads.

Minor arterials and other principal arterials make up about 77 percent of the total miles of state road maintained in south-central Kansas. Many of these roads were not designed to handle heavy trucks. Grain trucks cause road damage cost to increase rapidly on roads not designated for heavy vehicles. The majority of farm-to-elevator roads are local roads, collectors, and minor arterials. On the other hand, incremental road damage cost for intercity grain traffic could have been

TABLE 1 ANNUAL PAVEMENT DAMAGE COSTS FOR FARM-TO-ELEVATOR GRAIN MOVEMENT, BY ROAD SYSTEM AND ROAD TYPE, FOR PRE- AND POSTABANDONMENT PERIODS

Road/System Road Type	Pavement Damage Costs (\$)		Abandonment Cost (\$)
	Pre-Abandonment	Post-Abandonment	
State			
Arterial	299,688	430,559	130,871
Collector	3,982	7,039	3,057
Interstate	-	-	-
Sub-Total	303,670	437,598	133,928
Municipal/City			
Arterial	127	255	127
Collector	-	-	-
Interstate	-	-	-
Sub-Total	127	255	127
County			
Local	17,584	21,802	4,218
Sub-Total	17,584	21,802	4,218
Total	321,381	459,655	138,274

TABLE 2 ANNUAL PAVEMENT DAMAGE COSTS FOR INTERCITY GRAIN MOVEMENT, BY ROAD SYSTEM AND ROAD TYPE, FOR PRE- AND POSTABANDONMENT PERIODS

Road System/ Road Type	Pavement Damage Costs (\$)		Abandonment Cost (\$)
	Pre-Abandonment	Post-Abandonment	
State			
Arterial	231,657	280,580	48,924
Collector	2,522	4,398	1,876
Interstate	650	456	(193)
Sub-Total	234,828	285,435	50,607
Municipal/City			
Arterial	1,794	1,752	(42)
Collector	-	-	-
Interstate	-	-	-
Sub-Total	1,794	1,752	(42)
County			
Local	733	6,129	5,395
Sub-Total	733	6,129	5,395
Total	237,355	293,316	55,961

much more had not some portion of traffic traveled on roads designed to handle heavy loads. These highway routes include some major arterial sections along U.S. Highway 50 (southwest of Hutchinson) and U.S. Highway 54 (west of Wichita).

The goal of public policy is to come up with measures to minimize damages to Kansas roads resulting from shifts in modal choice and traffic patterns that result from rail abandonments. Two general choices come to mind: (a) a state-supported short-line rail program to keep branch line abandonments to a minimum, and (b) additional road funding to

upgrade roads in areas facing severe impacts from rail branch line abandonment.

This analysis demonstrates the usefulness of the methodology for estimating additional truck damage to Kansas roads in the event of branch line abandonment. This methodology will enable planners and policymakers to determine the impact of proposed abandonments and hence will provide an additional decision tool for use in choosing among various alternative strategies for responding to decisions by rail carriers to abandon service on branch lines in Kansas.

TABLE 3 PAVEMENT DAMAGE COST (IN CENTS PER BUSHEL-MILE) CAUSED BY RAIL ABANDONMENT, BY MOVEMENT TYPE

Movement Type/ Road System	Abandonment Cost (in cent/bu-mile)
Farm-to-Elevator	
State	0.87
Municipal/City	0.00
County	0.03
Sub-Total	0.90
Elevator-to-Market	
State	0.15
Municipal/City	-
County	0.02
Sub-Total	0.17

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